International Journal of Biodiversity and Conservation

Volume 6 Number 2 February 2014

ISSN 2141-243X

Academic Journals

ABOUT IJBC

The **International Journal of Biodiversity and Conservation (IJBC)** (ISSN 2141-243X) is published Monthly (one volume per year) by Academic Journals.

International Journal of Biodiversity and Conservation (IJBC) provides rapid publication (monthly) of articles in all areas of the subject such as Information Technology and its Applications in Environmental Management and Planning, Environmental Management and Technologies, Green Technology and Environmental Conservation, Health: Environment and Sustainable Development etc.
The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in IJBC are peer reviewed.

Submission of Manuscript

Please read the **Instructions for Authors** before submitting your manuscript. The manuscript files should be given the last name of the first author

Click here to Submit manuscripts online

If you have any difficulty using the online submission system, kindly submit via this email ijbc@academicjournals.org.

With questions or concerns, please contact the Editorial Office at ijbc@academicjournals.org.

Editorial Board

Instructions for Author

Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The **cover letter** should include the corresponding author's full address and telephone/fax numbers and should be in an e-mail message sent to the Editor, with the file, whose name should begin with the first author's surname, as an attachment.

Article Types
Three types of manuscripts may be submitted:

Regular articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly.
Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

Review Process

All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review.
Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors as fast as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the AJFS to publish manuscripts within weeks after submission.

Regular articles

All portions of the manuscript must be typed double-spaced and all pages numbered starting from the title page.

The Title should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and E-mail information. Present addresses of authors should appear as a footnote.

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 200 words in length.. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited.
Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard **Abbreviations** should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the solidus presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not be defined.

The Introduction should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

Materials and methods should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

Results should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

The Discussion should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc should be brief.

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

Figure legends should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or Powerpoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

References: In the text, a reference identified by means of an author‘s name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author‘s name should be mentioned, followed by ’et al‘. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like ’a‘ and ’b‘ after the date to distinguish the works.

Examples:

Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998; 1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)
References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. Afr. J. Biotechnol. 7: 3535-3539.

Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant Staphylococcus aureus in community-acquired skin infections. Emerg. Infect. Dis. 11: 928-930.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

Short Communications

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.
Proofs and Reprints: Electronic proofs will be sent (e-mail attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.

Fees and Charges: Authors are required to pay a $550 handling fee. Publication of an article in the International Journal of Biodiversity and Conservation is not contingent upon the author's ability to pay the charges. Neither is acceptance to pay the handling fee a guarantee that the paper will be accepted for publication. Authors may still request (in advance) that the editorial office waive some of the handling fee under special circumstances

Submission of a manuscript implies: that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis) that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the authors agree to automatic transfer of the copyright to the publisher.

International Journal of Biodiversity and Conservation

Table of Contents: Volume 6 Number 2 February, 2014

ARTICLES

academicJournals

Vol. 6(2), pp. 121-131, February 2014
DOI: 10.5897/IJBC2013.0645
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Review

Forest resource management systems in Ethiopia: Historical perspective

Amogne Asfaw Eshetu

College of Development Studies, Ababa University, Ethiopia.

Accepted 11 November, 2013

The integration of economic development and environmental management has become a major concern for society, businesses and governments, especially during the past century. A desk review was carried out to examine the various forest resource management systems used in Ethiopia over the past half century. Forest resources in Ethiopia have been managed with different intentions and motivations at different times; these management systems can be broadly categorized by prominent resource management paradigms, like frontiers economics, deep ecology, environmental protection, resource management, and eco-development. Three main forest development periods are identified: pre-derge environmental protection, derge regime environmental protection and frontiers economics, and post-derge resource management and environmental protection. We suggest that for long-term sustainable forest management to succeed, a combination of resource management and eco-development paradigms should be promoted.

Key words: Ethiopia, natural resource, natural resource management paradigm, forest, forest degradation.

INTRODUCTION

Economic development takes place in the environment using resources so that the environment is the natural resource base that sustains all life including human life (Dessalegn, 2001; Barrow, 2005). Both environmental management and development before the 1960s were top-down activities, but they now seek popular participation or even empowerment: the environment and people were once to be conquered, today they are to be understood as part of the planning process. Most adopt an anthropocentric viewpoint, placing humans first and environment second; however, there are environmentalists who are more ecocentric and regard environmental care to be at least as important as human needs (Barrow, 2005).

From 1949 to the early 1970s, economic development was concerned primarily with the reduction of poverty; environmental concern was deemed irrelevant, a 'luxury' that poor people could not afford, or was even seen as part of a scheme to hold back the less-developed nations. It was not until around 1987 that it was widely accepted that development needed effective environmental management and vice versa (Barrow, 2005). The subject of environmental management and its integration with development has become a major concern for people, businesses and governments of the world especially after the United Nations (UN) conference on environment and development held in Rio de Janeiro, Brazil (1992). It was a landmark in the evolution of an international consensus on the relationships among population, development and environment, based on the concept of sustainable development (UN, 1993); and then after, the relationship between environmental management with human development was in a period of dramatic change.

E-mail: amuvenu@yahoo.com. Tel: +251(0)913423595.

According to Colby (1991), five fundamental paradigms of environmental management systems which involve increasing integration of economic, ecological and social systems into the definition of development and the organization of human societies have been developed. These are:

Frontier economics

This was a paradigm prevailing in most countries until the 1960s and in some developing countries till now (Barrow, 2005). This paradigm treats nature as an infinite supply of physical resources to be used for human benefit, and as an infinite sink for the by-products of the consumption of these benefits, in the form of various types of pollution and ecological degradation. Managing the environment is more or less irrelevant because it is 'outside' economics (Colby, 1991; Barrow, 2005). According to Miller (1989), Cornucopians called "unrealistic technological optimists" by their opponents believe that if present trends continue, economic growth and technological advances will produce a less crowded, less polluted and more resource-rich world. For these groups, the current environmental problems are exaggerated and can be cured through technological innovations. They believe that the world will not run out of potentially renewable resources because of better management or a switch to substitutes; the earth's wild plant and animal species are here to serve our needs. Increase in economic growth and technological innovation can reduce resource depletion, pollution and environmental degradation to acceptable levels.

Deep ecology

The polar opposite of frontier economics, deep ecologists advocate merging appreciation of some of the more scientific aspects of systems ecology with a 'biocentric' (non-anthropocentric) or 'harmonious' view of the relationship between man and nature (Colby, 1991). Devall and Sessions (1985) as cited in Barrow (2005), called the paradigm a dark-green (deep-green) philosophy with an ecocentric rather than anthropocentric outlook. It advocates a harmony between humans and nature; it opposes the use of technology, and voices a wish to develop new ethics and development outlooks. Deep ecologists see technological fixes as usually leading to larger, costly, more intractable problems, rather than progresses (Colby, 1991).

Environmental protection

This is developed after the mid 1960s, this paradigm makes trade-offs between development and environmental protection. Tools like environmental impact assessment (EIA) were developed, and remedial measures were promoted to counter environmental damage. The norm was to seek 'end-of-pipe' pollution treatment or more-or-less managed dispersal (Colby, 1991; Barrow, 2005). This approach is inherently defensive or counteractive in practice and it has also been described as the 'business-as-usual plus a treatment plant approach.' The prescription of new technological solutions to mitigate pollution problems has also become part of this strategy. It focuses on setting the limits, and in some cases, cleaning up after limits are exceeded, but they are not responsible for planning development activities in ways that do not pollute or damage necessary ecological functions (Colby, 1991).

Resource management

This is developed in response to the fears that development would outstrip natural limits and cause disaster (Barrow, 2005). The basic idea is to incorporate all types of capital and resources into calculations of national accounts, productivity, and policies for development and investment planning.

Eco-development

This appeared in the early 1980s (Glaeser, 1984 as cited in Barrow, 2005) and emphasized the need to restructure society and economics to ensure that development worked with, rather than against, nature. According to Colby (1991), the relationship between society and nature in eco-development paradigm results to a *positive sum game or win-win outcome* by reorganizing human activeties so as to be synergetic with ecosystem processes and services. It advocates *pollution prevention pays* rather than *polluter pays*. It gives more emphasis for preventive measures than corrective action. Eco-development thus moves on from economizing ecology to ecologizing the economy which means designing an economic activity which is compatible to the ecology.

According to Ministry of Finance and Economic Development (MoFED) (2006), resource mismanagement coupled with their underutilization has so far reduced their contribution to Ethiopia's overall development. Over grazing and the expansion of farming into unsuitable land, caused by increasing population and livestock, without increasing economic productivity is leaving the land bare. As a result, large areas of the country, particularly on the northern and central highlands, have been exposed to loss of fertility, degradation and ecological imbalances. Dessalegn (2001) has strongly argued that the root cause of deforestation is absence of ownership security. According to EPA (2000), in order to ensure that future developments in Ethiopia are sustainable, it is essential to integrate environmental concerns into development activities so that the inclusion of the principles of sustainable development into development proposals is very essential. As a result, one of the key objectives of the EIA process is to integrate environmental considera-

tions in development planning processes in order to make use of natural resources in a responsible manner.

The objective of this paper was, therefore, to examine forest resource management systems of Ethiopia starting from the emperor period (1930-1974) till now (green economy of EPDRF) mainly based on literature review. In doing so, different documents, research findings, proceedings and regulations of the country were reviewed and analyzed from the major natural resource management paradigms point of view.

FOREST RESOURCE BASE OF ETHIOPIA

Diverse physiographic, altitudinal, climatic and edaphic resources, enables Ethiopia to have various types of vegetation ranging from alpine to desert plant communities (Sahle, 1984) which provide economical, socio-cultural and environmental benefits. Curry-Lindahl (1972), Sahle (1984), Gebremarkos (1998), Demele (2001), FAO (2003) and Tsegaye (2006) showed that forests have an important role in maintaining the productivity of the environment; trees provide food for animals, serves as a standing cover to protect the land from wind and water erosion, stabilizing the water cycle, facilitates the process of evaporation and keeps the soil porous; they are also used for construction as well as for tools, furniture, fuel, medicine, grass and herbage, for forage and provide edible fruits. They serve to absorb carbon-dioxide to reduce global warming, give off oxygen and renewing the atmosphere. Plants also serve as source of income by attracting tourists, serve as recreational facilities; prevent lakes and dams from silting; clean, regulate and distribute water resources.

Even though natural resources in Ethiopia have great contribution to development, most of natural resources are highly exposed to degradation (Demel, 2001). Gebremarkos (1998:28) stressed that “historical evidences revealed that a few hundred years ago more than 63% of the total land mass of Ethiopia was covered by dense forests but it is not greater than 3% now.” In relation to resource depletion, EPA (1998), Reusing (2000), Badege (2001), Tarekegn (2001), FAO (2003), Yitebitu et al. (2010), Alemu and Abebe (2011) and Million (2011) argued that Ethiopians are facing rapid deforestation and land degradation that has been fueled by increase of population which in turn resulted in extensive forest clearing for agricultural use, overgrazing, exploitation of existing forests for fuel wood, fodder and construction materials, setting of fire to create pasture land and expansion of settlements. As a result, there has been a rapid decreasing percentage of the forest cover of the country from 40% in 1900 to 16% in 1954, 8% in 1961, 4% in 1975, 3.2% in 1980 and now it is estimated to be less than 3%. Most scholars agreed that current rate of deforestation is estimated to be 160,000-200,000 hectares per year (Ferede, 1984; Gebremarkos, 1998; EPAE, 2002) which is extremely high. According to Ethiopian news agency (July 14, 2010) by referencing the ministry of agriculture and rural development, it was confirmed that the forest coverage of Ethiopia has increased from 3% in 2000 to 9% due to the afforestation campaign launched all over the country in the last ten years (but this data could not be validated with published government sources).

According to Dessalegn (2001), state natural resource policy was also responsible for aggravating the process of land degradation. The imperial regime laid claim to all “unutilized” land, land that had no “legal” owners, and all forests, lakes and river systems which ended up with friction between communities and the government. To deny the state rights over a given piece of land, individuals cleared it of vegetation and ploughed it up; large tracts of pastureland, land that was fragile in nature and forestland were changed into cultivable land in the 1950s and 1960s. This alarming rate of deforestation is the major cause of the disappearance of various indigenous wild animals and plants, and it has also brought about adverse effects on the country’s tourism industry, bio-diversity and economy, among others (EPAE, 2002). Table 1 illustrates how deforestation was and still a critical problem in Ethiopia.

Forest destruction results multifaceted problems. Studies by Curry-Lindahi (1972) and Demele (2001) described the effects of deforestation as a change of micro/macro climate and in hydrological cycles, causes the disappearance of wild animals, birds and reptiles, affects the natural beauty of an area, accelerates run off and soil erosion, shortage of rainfall, increase in siltation of dams and reservoir, results to increase in carbon dioxide that in turn causes an increase in temperature, causes extinction and loss of economically important indigenous plant and animal species, and land degradation greatly affects agricultural productivity and production. The current government of Ethiopia clearly articulated the seriousness of forest destruction in the Climate Resilient Green Economy (CRGE) document (FDRE, 2011) and as a solution, reduction of demand for fuel wood by disseminating fuel efficient stoves; increasing afforestation and reaforestation schemes; and promoting area closure via rehabilitation of degraded pastureland and farmland are forwarded as a viable strategy.

Tree planting activities has a long history in Ethiopia. According to historical records, afforestation started in the early 1400s by the order of King Zera- Yakob (1434-1468) but modern tree planting using introduced tree species (Australian Eucalyptus) was started when Emperor Menillik II (1889-1913) looked into solutions for alleviating shortage of firewood and construction wood in the capital, Addis Ababa. During the Derge regime (1974-1991), rapid expansion of large scale and community plantations occurred which resulted in the establishment of large scale plantations mainly for supplying the huge demand for wood products in Ethiopia (Yitebitu et al., 2010). For instance, in 1981, peri-urban fuel wood plantation projects were launched in Addis Ababa, Nazareth

Table 1. Deforestation estimates in Ethiopia by forest type (in hectare) 1994-2003 E.C.

Type	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Highforest	270 897	118 355	99 601	73 025	57 182	48 235	66 036	76 412	73 875	76 723
Wood land	83 720	77 929	75 460	79 195	83 379	85 365	86 611	91 038	95 633	96 323
Shrub land	44 678	51 432	56 752	59 377	77 242	70 164	68 051	65 548	61 854	58 685
Total*	399295	247716	231 813	211 597	217803	203764	220698	232998	231362	231 731

Source: Ministry of Agriculture and Rural Development (2004) as cited in EPA, 2004: Annex XII. *Total computed by the author.

and Debre Berhan and latter in Gondar and Dessie (EPA, 1998). This is a type of environmental protection paradigm because the plantation scheme was undertaken in response to critical shortage of fuel wood. Environmental protection by its nature (Colby, 1991) is a defensive or remedial in practice and legalizes the environment as an economic externality. Rather than showing the ecological impact of forest destruction, more emphasis was given to its economic benefit (source of fuel).

FOREST RESOURCE MANAGEMENT SYSTEMS IN THE PRE-*DERGE* PERIOD (BEFORE 1974)

In the past, large forests were managed as crown property by emperors and kings basically as sources of fuel wood and timber for the royal households. Such forests were protected and encroachment was forbidden (perhaps it may be for the peasants) (Dessalegn, 2001). According to Sisay (2008), the first elaborate and modern legislation on forest resources came during emperor Haile Selassie I (1930-1974) in 1965 which gave recognizition for three forms of forests (namely state forest, private forest and protected forest). The main objective of the forest legislation during the 1960s was not so much to promote resource conservation but rather to enlarge the sources of state revenue (Dessalegn, 2001). This shows that the forest resource management paradigm during that time was environmental protection type because the forests were preserved and protected for their economic value mainly as a source of fuelwood and construction material. In addition, little attempt was made for new plantation. The Ethiopian forestry association (EFA), which was set up in 1960, launched a farm woodland campaign to encourage peasants to plant trees on their plots as an economic and conservation measure (Dessalegn, 2001) is one indicator for this.

In the mid-1960s, an extensive deforestation took place following the promulgation of a series of forest legislation because the legislation placed all large forests under state ownership, and put severe restrictions on the use and management of private forests (Dessalegn, 2001). Another scenario during the imperial regime regarding forest resource was the expansion of large-scale, comercial agriculture, which was actively encouraged by the state, at the expense of the forests with an objective of increasing agricultural production (Dessalegn, 2001). This is rather a typical example of frontier economics type of resource management paradigm.

Dessalegn (2001) argued that there was a limited attempt by the imperial government to promote forestry in the country and to protect state forests in the early 1960s. During the second half of the 1960s, the government began to show greater concern for environmental problems and undertook several initiatives to promote afforestation and soil and water conservation. In response to pressures from different corners, several national parks and game reserves were set up in various parts of the country in the second half of the 1960s and the early 1970s with the support of UNESCO and expatriate staffs. The schemes were restrictive and had a damaging impact on the livelyhood of the people who lived in and around them (Dessalegn, 2001). This seems to be environmental protection paradigm type because the measures were taken in response to massive forest destruction due to state farm expansion. In environmental protection paradigm, remedial actions are taken after a certain intervention arises with negative externalities. They are not responseble for planning development activities in ways that do not pollute or impair necessary ecological functions. As a remedial solution, relatively small parcels of common property resources are converted to state property to be set aside for preservation or conservation as national parks and wilderness reserves (Colby, 1991).

FOREST RESOURCE MANAGEMENT SYSTEM DURING *DERGE* REGIME (1974-1991)

In 1980, *Derge* proclaimed a new law called forest and wildlife conservation and development proclamation No. 192/1980 by accusing the previous government of its improper and unplanned exploitation of the country's forest resources and stated that the forest cover was depleted because of the selfish interest of the aristocracy and the nobility (Sisay, 2008). Paradoxically, according to Yeraswork (2001), natural forests were used as spring boards for plantations that outwardly expanded at the expense of peasant holdings during the *Derge* regime in the course of time, which turned community members against the resources. Dessalegn (2001) described the situation as "many of the state forests managed by the ministry of agriculture during the *Derge* regime were enlarged by expropriating farms or grazing land. Afforestation

thus posed a threat to many peasants because it encroached on farmland, evicted households living in or near it, and took away land that was common property and had economic, social or cultural value".

Later on, *Derge* applied mass mobilization and forced labor campaigns to rehabilitate degraded lands with vegetation and area closure scheme was designed. Such areas were frequently employed for grazing by the community because alternative sources of pasture were not provided (Dessalegn, 2001). As explained by Million (2011), plantation forests during that time were mainly for commercial timber- for sawn wood and poles as well as non-industrial plantations like fuelwood and construction timber. State environmentalism during the *Derge* era, as argued by Dessalegn (2001), had placed high emphasis on government control of environmental assets on one hand, and the protection of such assets by restricting or prohibiting their utilization by the surrounding community on the other hand. From this, one can conclude that the forest management system during the *Derge* period was again the environment protection type. Forests were protected mainly for their economic value. Area closure, construction of check dams, establishment of national parks, gully control and reafforestation schemes undertaken were some instances that show how the strategies were corrective in practice rather than being preventive. The majority of these 'community forests' were destroyed during the conflict and transition after the downfall of the *Derge* (1991) because they were undertaken without the consent of the locals with the exception of the few cases where such forests were preserved by local communities often with backing of Christian or Muslim religious leaders and institutions (Pankhurst, 2001).

Tarekegn (2001) also pointed out the scenario as "after the fall of the regime there was widespread deforestation of forest areas, which were seen by the local population as state forests". Tenure insecurity and memories of coercive government for over two decades have made the local population suspicious of government controls in land and natural resource management. Afforestation schemes, national parks and areas designated for rehabilitation were closed to peasants and pastoralists who were not allowed to gain any benefits from them (Dessalegn, 2001).

According to EPA (1998:49), the most negative environmental impact during the *Derge* regime came from policy and regulatory interventions that increasingly and cumulatively eroded the rights of individuals and communities to use and manage their own resources. "Protected areas and national parks in the dry lands suffered greatly as trees were cut and vast areas were set on fire. People perceived that they had no secure land and tree tenure and the state was not able to enforce its own regulations of forest protection and environmental conservation".

Other events which led to massive degradation of forest resources during the *Derge* regime were programme of mass resettlement and villagization following the 1984/5 famine that was done with the intention of transforming rural life with radical land reform, the establishment of rural co-operatives and state farms. But much of these were done with extreme coercion (Harrison, 2001). Programs designed by the *Derg*e like collectivization, villagization and resettlement approaches were implemented with devastating effects on forest resources of the country (Tarekegn, 2001; Messay and Bekure, 2011). Dessalegn (2001:38) elaborated the situation as "…many rural policies were worked against environmental objectives. Collectivization, villagization and resettlement, which were carried out on a large scale in the 1980s, were accompanied by extensive deforestation and soil erosion". He further added that the land reform and the periodic redistribution of farm plots undermined security of holdings which discouraged peasants from investing on the land or employing conservation measures. On the contrary, illegal cutting of trees, the grazing of livestock in closed areas, the uprooting of tree seedlings planted in forest schemes and the invasion of natural parks were intensified.

In addition to resettlement programs, large scale deforestation was carried out as a result of expansion of state farms (Dessalegn, 2001). For instance, *Derge* designed resettlement as a principal strategy to ensure food security and ease the pressure on densely populated highlands. A massive emergency resettlement program were launched into sparsely populated areas as well as into underutilized peripheral lowlands after the 1984/85 droughts and famine. This is the part of the country where the remaining forests are confined (Reusing, 2000). The resettlement programs caused serious natural destruction on indigenous trees and on wildlife. The road access created by the resettlement program also facilitated over exploitation of forest and forest products (Mekonnen et al., 2011). Reusing (2000:1256) has described the situation as:

> …at the beginning of this century [20th century], the southwestern part of the Ethiopian highlands had been completely covered by montane rainforests. The situation changed with new settlers migrating from the central and northern parts of the country to this area. With the new settlers, a new farming system was introduced which did not adapted to the environmental conditions in the area.

The resettlement scenario and its consequence on forest resources during the *Derge* regime can be categorized as frontier economy paradigm type. As depicted in the above explanation, the concern was on achieving food security at the expense of forest resource. It was totally anthropocentric in its nature. According to Colby (1991), frontier economy paradigm treats nature as an infinite supply of physical resources (including forest) to be used for human benefit, and as an infinite sink for the by-products of the consumption of these benefits, in the form of various types of pollution and ecological degradation.

Case 1: Massive destruction of forest resource during the transition period (early 1990s)

State forestry under the *Derge* posed a threat to peasant livelihoods; it encroached on farm land, evicted households living in and near it, and took away land that was customarily used for grazing. Many of the forests in question were enlarged by expropriating farmland and pasture. The resources of these forests were close to the surrounding peasants, which were not allowed to graze their animals on them, nor cut grass or wood. Peasants carried on covert resistance against the schemes. They complained about area closures because these involved the loss of access to grazing land; closures were not accompanied by alternative sources of pasture. As a result of this, the attack on the environment, after the fall of the *Derge* regime, was not organized by anyone; it was rather spontaneous and anarchic. Peasants and others demolished bunds and terraces, set fire on forests and national parks, "illegally harvested" trees from government plantations, uprooted young saplings in freshly afforested or enclosed areas. Perhaps as much as 60% of the conservation assets created during the military dictatorship may have been destroyed during these two years (1991/1992). There were numerous cases of arson in national parks, and some of the big game reserves in the south of the country were badly damaged. Extracted from Dessalegn (2001; 52-80)

From the above case, one can conclude that any natural resource management system implemented without the consent and participation of the community ends up with destructive long term outcome. So long as the intervention is to enhance the productivity of nature and to improve the livelihood of local community, locals have to actively participate right from the outset to the completion of the program; and they have to be the number one beneficiaries.

FOREST RESOURCE MANAGEMENT SYSTEM (SINCE 1991)

In 1994, a new proclamation came into picture, namely, "forest conservation, development and utilization" proclamation no. 94/1994 and another great endeavor was the establishment of Ethiopian forestry action program (EFAP), which is a working document that has direct relation with forest development and conservation. EFAP set forth as objectives of forestry development, to sustainably increase production of forestry products, to increase agricultural production by reducing land degradation and increasing soil fertility, to conserve forest ecosystems and to improve the welfare of rural communities. The policy put general direction wherein, among others, expansion of forests and agro-forestry is needed to accelerate economic development of the country (Sisay, 2008). Additionally, EIA proclamation with an emphasis on the utilization of forests should be only with their regenerative capacity, which was amended in 2002 by Proclamation No. 29/2002. That means forest management that accounts for the sustainable supply without affecting environmental and social amenities derived from the forests is needed. Since free grazing affects natural regeneration of valueble indigenous trees, the policy restricts free grazing in protected forest areas (Sisay, 2008).

In 2007, the council of ministers adopted a forest policy which gives due attention to forest development and conservation considering its significance to the national economy, food security and sustainable development of the nation (Sisay, 2008). The overall objective of the policy is "to conserve and develop forest resources properly so that there could be sustainable supply of forest products to the society (hence satisfying the demand) and contribute to the development of the national economy." As stated in forest development, conservation and utilization proclamation No. 542/2007 (FDRE, 2007), in order to properly conserve, develop and utilize the forest resources of the country, major forestlands should be designated as state forests, their boundaries should be demarcated with the participation of the local community and they should be registered as protected and productive forests (article 8:1); forests shall be protected from forest fire, unauthorized settlement, deforestation, undertaking of mining activities and other similar dangers (article 9:7). It also stressed that the local community may reap grasses, collect fallen woods and utilize herbs from a state forest in conformity with the management plan developed for the forest by the appropriate regional body. The harvesting of forest products, grass and fruit as well as the keeping of beehives in state forests may be permitted based on the objective realities of the locality (Article 10:3-4) and state forests shall be used to generate income from tourism (Article 10:5).

The objectives mentioned here (both in EFAP, forest development, conservation and utilization Proclamation and EIA proclamation), have both economic as well as environmental out comes. From this, one can say the objectives have been designed based on resource management type of paradigm because most of the strategies (like agroforestry, increasing fertility of soil, increasing the productivity of the existing land, expansion of off-farm economic activity on forests like apiculture and tourism) focus on preventive rather than corrective actions. More emphasis has been given to strategies which minimize the demand of forest resources like agroforestry that reduces the pressure on the remaining forests for need of fuelwood and incrassating the fertility of soil as well as livelihood diversification so as to decrease the need for additional land for cultivation at the expense of forests.

The role of environmental conservation for sustainable development has been boldly articulated in the growth and transformation plan (GTP) of the country. The main objectives for the environment and climate change initiatives in the GTP are to formulate and effectively implement

policies, strategies, laws and standards which will foster social and green economy development so as to enhance the welfare of citizens and environment sustainability. The document further added that, during the GTP period, soil and water conservation works will be implemented using organized community participation, in those areas where such works are required as well as forestry development, protection and utilization works will be carried out in a similar way (MoFED, 2010). In addition, one of the four pillars of the green economy plan of Ethiopia (FRDE, 2011) focuses on protecting and re-establishing forests for their economic and ecosystem services, including carbon stocks.

A plan for accelerated and sustained development to end poverty (PASDEP) document of the country has also gave especial emphasis on natural resource conservation and management and stressed that integrated development and utilization of the resource bases enables the transition to improved livelihoods, and to protect these resources for future generations. It was planned to rehabilitate about 4.7 million hectares of degraded areas so as to increase the forest coverage of the country (MoFED, 2006). Even though, this plan is a kind of resource management paradigm because it focuses on protecting and reestablishing forests for their economic and ecosystem services, the current deforestation in southwestern part of the country due to foreign investment and resettlement programs (Mekonnen et al., 2011; Dessalegn, 2011) makes the strategy rather a frontiers type of paradigm and it seems a paradox.

The GTP document highly underlined that deforestation and forest degradation must be reversed to support the continued provision of economic and ecosystem services and growth in GDP. Despite their economic and environmental value, Ethiopian forest resources are under threat and unless action is taken to change the traditional development path, an area of 9 million hectare will be deforested between 2010 and 2030. Over the same period, annual fuelwood consumption will rise by 65%, leading to forest degradation of more than 22 million tones of woody biomass (FDRE, 2011). In order to overcome the problem, strategies like dissemination and usage of fuel-efficient stoves, increasing afforestation/reaforestation schemes and promoting area closure via rehabilitation of degraded land, that could help to develop sustainable forestryandreducefuelwooddemand,havebeenarticulated.

In addition to the aforementioned strategies, the document proposed agriculture intensification on existing land so as to reduce pressure from agriculture on remaining forests (FDRE, 2011). Furthermore, avoiding deforestation is also pointed out as an important development objective hoping that it will preserve the natural ecosystem endowment and also contribute to a sustainable development of agriculture. In doing so, measures like improving the efficiency and productivity of existing cultivated land and land to be cultivated to reduce pressure on forests, as well as the substitution of traditional cooking techniques with efficient appliances, thus reducing fuelwood consumption and increasing carbon sequestration by forests will be carried out (FDRE, 2011).

Since deforestation rates in Ethiopia historically correlate with the expansion of agricultural land (FDRE, 2011), reducing the need for additional farm land enables to minimize the pressure on the remaining forests of the country. In line with this, the proportion of new land for agriculture that is taken from forests will decrease from 70 to 55% in 2030 (FDRE, 2011). Two million hectares of pastureland will be afforested up to 2030 and 1 million hectares of degraded land will be reforested (FDRE, 2011).

The CRGE document acknowledges both the economical as well as ecological contributions of forests and most of the strategies designed regarding the forest resource management of the country decrease the demand of forest resources. Strategies designed to realize these objectives includes dissemination of fuel efficient stoves, agricultural intensification and diversification, area closure, irrigation on non-forest areas, agro-forestry programs and planting trees outside forests. The target is to minimize the pressure of development endeavors over the remaining forests of the country and enhancing the productivity of the existing land. The strategies are more of preventive than corrective which is peculiar characteristic of resource management paradigm. In addition, an extensive watershed management program which incorporates afforestation scheme has been designed. This is more or less environmental protection type of paradigm because the action is corrective than preventive.

Though the CRGE has planned a resource management type of paradigm and there is rehabilitation through massive watershed program (more of environmental protection paradigm), what is actually happening in northwest, southwest and southern part of the country is frontiers economic type of resource management. In these areas, forest resources have been destroyed due to extensive investment and resettlement programs designed by the government.

Case 2: Resettlement in Nanno and its impact on forest resource of the area

Nanno wereda is found in West Shewa Administrative Zone of ONRS. Resettlement programs undertaken by EPDRF exert heavy pressure on destination areas, which in turn results in swift land-use/land-cover changes. Shrub-grassland is found to be the most shrinking land use type in the area. It reduced from 41.29% in 1984 to 24.43% in 2007. It shrank at the rate of 1.06 and 7.07% per year from 1984 to 1999 and 1999 to 2007, respectively. This change involved a gradual modification of the shrub-grassland to grassland or conversion to farm land. A significant conversion (7.07%) from natural vegetation cover to cropland and settlement area was observed more profoundly between 1999 and 2007 (Messay

and Bekure, 2011: 269).

Case 3: Impact of resettlement on forest resources

Most of the resettlement programs recently have been undertaken in Bench-Maji, Kaffa, Dawuro, Sheka, South Omo zones and Basketo special district as well as in the western lowlands of Tigray and Amhara regional states throughout the year. In Southern Nations Nationalities and Peoples Regional State (SNNPRS) and Oromia National Regional State (ONRS), the resettlement sites were covered either with dense forests or wooded grass land prior to the implementation of the resettlement. Resettlement sites like *Gabiqa* in Gurafarda district and part of the *Chewaqa* resettlement site were covered with dense forests when the first settlers arrived the areas. Out of the seven resettlement sites in *Chewaqa*, two of the sites were established by clearing dense tropical rainforests due to mismatch of the number of resettlers sent to the area and the size of land designated for the resettlement. In Amhara and Tigray regions, the wood land coverage reduced by 25.76% between 2000 and 2007 due to resettlement programs. Most of the wood land has been replaced by arable land for the cultivation of cash and food crops. The situation in SNNPRS and ONRS is harsh than ANRS and Tigray (Mekonnen et al., 2011:26-35).

According to Messay and Bekure (2011), "environment-induced resettlement is the most common incident in Ethiopia." They further urged (using satellite image data) that the shrub-grassland of the country is diminished alarmingly due to the removal of plants for farmland preparation, fuel wood, construction, charcoal preparation and traditional farm equipment making. Most vegetated land use/land cover types in 1984 and 1999 were alarmingly changed to cultivated land in 2007 (p 286). Unless appropriate environmental protection and rehabilitation measures are taken, vegetated land-cover types of Ethiopia are disappearing at frightening rate.

Regarding the impact of recent resettlement schemes on the forest resources of the country, Berhanu (2007) in his MSc work pointed out that the vegetation cover of *Chewaka* resettlement site (southwestern Ethiopia) has been reduced by 42.4% due to different human activities though the government claims that the resettlement programs are environment friendly. Furthermore, there are no conservation measures initiated in the area and calls for immediate intervention. Similar study by Dejenie (2011), the case of *Guraferda* woreda, southwestern Ethiopia, came up with similar result. Poor planned resettlement programme leads to uncontrolled encroachments and farmland expansions which have posed great damage on the vegetation composition and structure of the area. In addition, like that of *Chewaka* case, no intensive efforts were made to stop further deforestation; afforestation or planting activity in the area is negligible.

Case 4: Impact of resettlement on forest resource: Amhara National Regional State

Since 2003, the ANRS has resettled 166,204 household heads in six woredas of the region, namely Metema, Quara, Tegede, West Armachiho, Tach Armachiho and Jawi. The resettlement program was undertaken in areas where the soil and the vegetation are highly susceptible to human interference. For the purpose of the government-led resettlement, the scares forest lands were used and large area of woodland is converted into cultivation. Prior to the 2003 resettlement program, the total cultivated land area in Metema and Quara woredas was estimated to be 60,650 and 236,497 hectares (ha), respectively. Besides, the woodland coverage in the respecttive woredas was 232,001 and 535,537 ha. After the resettlement program was implemented, the total area of cultivated land for Metema and Quara woredas increased to 95,105 (10.8% increment) and 264,104 hectares (3.2% increment), respectively. On the other hand, the woodland area was decreased to 201,906 ha in Metema (9.5% decrease) and 493,969 ha in Quara (4.9% decrease). The annual decrease of the woodland in Metema and Quara was 4,299 and 5,938 hectares, respectively. These dramatic land use changes occurred over a period of less than a decade (Teshome et al. 2011:297-307).

In addition to the resettlement programs undertaken by the Ethiopian government, expansion of foreign investment has also been cited as a major challenge for the remaining forest resources of the country. Guillozet and Bliss (2011), in their work stressed that "foreign investment in Ethiopia's forestry sector is currently limited, but agricultural investments that affect forests, largely through forest clearing, are common place." Getnet (2012) on this part expressed his worry of expansion of foreign investment over the remaining forest resources that, numerous investors from Asia, the Middle East, Europe and the USA have acquired land in various parts of Ethiopia [some, like the Oakland institute (2011), called it land grabbing]. Over 35 Indian firms have acquired extensive tracts of land, especially in Benishangul and Gumuz, Gambella and ONRS. He further added that "in a number of project sites, large-scale land clearance is taking place, and the removal of woods and other vegetation has exposed the land to serious erosion and damage to natural water sources. Some investment projects are undertaken even inside the national parks and inside the established wildlife habitats (p.23)". This scenario clearly depicts that the current vast investment programs are launched in the part of the country where endemism is particularly high and where the remaining forests of the country are confined (EPA, 1998:17). ONRS, SNNPRS and Gambella region account for 95% of the total high forest resource of Ethiopia (Million, 2011:11).

Case 5: Impacts of foreign investment on forest resources

Following the international food crisis of the second half

of the 2000s which was accompanied by exceptionally high commodity prices and severe supply shortages in the world market, global land grabbing has spread rapidly. The rush for land in Africa by investors has also been driven by the assumption that land is abundant in the continent, land rents and labor costs are low, and there are few regulatory roadblocks restricting production and export. The commercialization of land and the shift to large scale agriculture is taken as an essential measure for agricultural modernization and the improvement of productive efficiency. As a result, total transfers of land from the late 1990s to the end of 2008 to both domestic and foreign investors in Ethiopia reaches almost 3.5 million hectares mainly in southwestern part of the country. Gambella (the region with a unique ecology and immensely rich in biodiversity) has become the major target point for foreign investors. The investments underway is to be found in many parts of the region, and some are inside the national park and protected areas [this was also confirmed by Oakland institute, 2011]. The clearing of the land and the large-scale deforestation has caused and will bring social and economic hardship and wildlife which used to be plentiful in the area, and which they hunted occasionally for consumption, have now disappeared (Dessalegn, 2011 extracted from page 1 to 21)

From the above discussion, as far as forest resource management is concerned, the paradigm type planned in CRGE and what is actually implemented (watershed mana-gement, foreign investment and resettlement) in the current government is somewhat a mixture of frontier economy (expansion of agriculture and settlement at the expense of forests), environmental protection (a corrective action through rehabilitation of formerly degraded areas) and resource management (a preventive action-by designing strategies to minimize the pressure on the remaining forest resources).

The Ethiopia's agricultural sector policy and investment framework strategic document (MoARD, 2010) under objective 3, assured that strategies should be designed to conserve and utilize Ethiopia's natural resources in a sustainable and productive manner. In addition, one of the specific objectives of the environmental policy of the country is to ensure that essential ecological processes and life support systems are sustained; biological diversity is preserved and renewable natural resources are used in such a way that their regenerative and productive capabilities are maintained. It advocates in incorporating the full economic, social and environmental costs and benefits of natural resource development into the planning, implementation and accounting processes (resource management type of paradigm) by a comprehensive valuation of the environment and the services it provides.

Though not significant in terms of area coverage, deep-ecology types of forest management systems are also found in Ethiopia. Forests in religious compounds and some scared areas are not used by local communities and they are preserved. Regarding this issue, Dessalegn (2001) explained that forestry on *asted* [church compound] and consecrated land is also protected by the church. The forest is consecrated because of the location of *tsebel* (holy water or spring which is believed to have medicinal benefits) in it. No one is allowed to cut trees from such forests because of the fear that the holy water will dry up if deforestation takes place. In addition, tree cutting in *wujjib* (a shrine and holy burial ground in Islamic religion) is not allowed except when there is a need to construct a new mosque. In addition to the *asted* and *wujjib* forests, scared forests are also respected due to different reasons by localities. Cardelus et al. (2003) also pointed out that many rare and endemic species are found only in sacred groves of churches. Thousands of these church forests currently exist as islands in a sea of degraded land where they have become centers of forest conservation; sacred sites have demonstrated remarkable resilience in the face of change.

CONCLUDING REMARKS AND THE WAY FORWARD

Ethiopia is endowed with diverse natural resource in general and forest resource in particular. But due to unwise use of the forest resource of the country which has been taking place for centuries, the remaining forest coverage is extremely very small and is confined in southwestern part of the country. The primary causes of natural forest destruction are agricultural expansion, both through shifting cultivation, large scale investment and the spread of sedentary agriculture; the demand for increasing amounts of construction material, forest fires, fuelwood and charcoal; as well as expansion of re/settlements and livestock grazing. In addition, charcoal production is common place in the arid, semi-arid and dry subhumid parts of the country (EPA, 1998). Governments of Ethiopia, both in the past and at present, tried to implement different interventions to rehabilitate the degraded areas and to maintain the remaining forests (though most of the economic policies rather aggravated and still are aggravating the rate of forest destruction). The strategies selected can be categorized broadly as frontiers economics, environmental protection and resource management paradigms. There are some instance which resembles deep-ecology (mainly in religious institutions) and eco-development (like ecotourism, apiculture and zero grazing) but not pervasive like the others. Because of the economic, socio-cultural and ecological significances of forests, due attention should be given to their management. In doing so, priority should be give to resource management and eco-development type of paradigms. The following strategies, if implemented properly, would have a win-win outcome:

1. Provision of alternative source of energy (for cooking, baking and lightening) minimizes the demand for fuel food.

2. Livelihood diversification and agricultural intensification (expansion of non-farm economic activities like ecotourism, agro-forestry, apiculture, highland fruit productions, livestock fattening through cut and carry method) minimizes the pressure on the remaining forest resources of the country.
3. Forest tenure security encourages peoples to have their wood lots for fuel wood and construction so that it is possible to minimize the pressure on the remaining natural forests
4. Reversing the paradox- rehabilitation of the degraded area (resource management and eco-development paradigm) versus degrading the remaining forest resource (frontiers and environment protection paradigm) has to be checked. Rather than converting forest and wood lands into agricultural land (be it investment or small holder agriculture), it is better to enhance the productivity of the existing cultivated land in one hand and develope eco-friendly economic activity on the remaining forest resources (like apiculture, ecotourism, fruit and spices production)
5. Resettlement program might have a short term advantage, especially to be able to feed the food insecured portion of the population. But its long lasting effect on the forest resources of the destination area is devastating. So, rather than targeting on it, it would rather be better to enhance the productivity of land, expanding off-farm economic activities and the like. When resettlement is the only option to be applied, special attention should be given to minimize its adverse effect. In addition, priority should be given to eco friendly economic activities rather than agriculture or intensification has to be used in order to minimize additional demand of cultivable land at the expense of forests and woodlands.

REFERENCES

Alemu M, Abebe D (2011). Private trees as household assets and determinants of tree growing behavior in rural Ethiopia. Environment for development; discussion paper series (EfD DP 11- 14). Addis Ababa, Ethiopia. pp. 1-5.

Badege B (2001). Deforestation and land degradation on the Ethiopian highlands: strategy for physical recovery. Northeast African studies; 8(1):7-26.

Barrow CJ (2005). Environmental management and development. Taylor & Francis Group, London: pp.10-27

Berhanu G (2007). The impact of resettlement on woodland vegetation: the case of Chewaka resettlement area, southwestern Ethiopia. MSc thesis; Addis Ababa University.

Cardelus C, Peter SP, Hair J, Baimas GM, Lowman M, Alemayehu W (2003). A preliminary assessment of Ethiopian sacred grove status at the landscape and ecosystem scales. Diversity *5*:320-334.

Colby ME (1991). 'Environmental management in development: the evolution of paradigms'. Ecol. Econ. 3:193-213.

Curry-Lindahl K (1972). Conservation for survival: Ethiopia's choice. HIS University press; Addis Ababa, Ethiopia.

Dejenie A (2011). Impact of resettlement on woody plant species and local livelihood: the case of Guraferda woreda in Bench Maji zone, southwestern, Ethiopia. MSc thesis; Addis Ababa University, Ethiopia.

Demele T (2001)."Deforestation, wood famine and environmental degradation in Ethiopia's highland ecosystems." Northeast African Studies 8(1):53-76.

Dessalegn R (2001). Environmental change and state policy in Ethiopia: lessons from past experience. Forum for social studies monograph Series 2. Addis Ababa. Ethiopia. pp. 10-108.

Dessalegn R (2011). Land to investors: large-scale land transfers in Ethiopia. Forum for Social Studies; Addis Ababa, Ethiopia. pp. 1-12.

Environmental Protection Authority/EPA/ of Ethiopia (1998). Democratic republic of Ethiopia national action programme to combat desertification. Addis Ababa, Ethiopia. pp. 17-87.

Environmental Protection Authority /EPA/ of Ethiopia (2000). Environmental impact assessment guideline document (final draft). Addis Ababa, Ethiopia. pp. 3-43.

Environmental Protection Authority/EPA/ of Ethiopia (2002). Deforestation leaves two million hectares of land barren in Ethiopia. WIC, January 12, Addis Ababa, Ethiopia. Retrieved from www.geocities.com/akababi/news1/nwjan1402.html on 11/05/2013.

FAO (2003). "Role of planted forests and trees outside forests in sustainable forest management in the republic of Ethiopia." Working paper 29, Rome. pp. 13-40.

Federal Democratic Republic of Ethiopia (FDRE) (2007). Forest development, conservation and utilization proclamation no. 542/2007. Negarit Gazetta No 56. Addis Ababa, Ethiopia. pp. 1-14.

Federal Democratic Republic of Ethiopia (FDRE) (2011). Ethiopia's Climate-Resilient Green Economy: Green economy strategy. Addis Ababa, Ethiopia. pp. 2-114.

Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development (MoARD) (2010). Ethiopia's agricultural sector policy and investment framework 2010-2020, Addis Ababa, Ethiopia.

Gebremarkos W (1998). "The forest resources of Ethiopia: past and present." J. Ethiop. Wild Life Natural History Society: Walia p.19.

Getnet A (2012). "Rural land policy, rural transformation and recent trends in large-scale rural land acquisitions in Ethiopia." European Report on Development. pp. 17-23.

Harrison E (2001). "Participation and partnership in resource management." In Pankhurst A (edt.) Natural Resource Management in Ethiopia. Addis Ababa, Ethiopia.

Mekonnen Y, Moti J, Adugna T, Mitiku H, Ansha Y, Kindeya G, Kelemework T, Yemane G, Mekonnen T (2011). Impact of resettlement on the livelihood, food security and natural resource utilization in Ethiopia**.** Dry lands coordination group report. pp. 65:1-35.

Messay M, Bekure W (2011). The impact of resettlement schemes on land-use/land cover changes in Ethiopia: a case study from Nanno resettlement sites, central Ethiopia**.** J. Sustainable Develop. Afr. 13(2):269-293.

Miller TG (1989). Resource Conservation and Management. Wadsworth publishing company; Belmont, California. pp. 20-21.

Million B (2011). "Forest plantations and woodlots in Ethiopia*"* African Forest Forum*;* 1(12):11-15*.*

Ministry of Finance and Economic Development (MoFED) (2006). Ethiopia: building on progress-A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10); Volume I: Main Text. Addis Ababa, Ethiopia. pp. 85-190.

Ministry of Finance and Economic Development (MoFED) (2010). Growth and Transformation Plan of the Federal Democratic Republic of Ethiopia 2010/2011-2014/2015; main text. Addis Ababa, Ethiopia. I:50-120.

Oakland Institute (2011). Understanding land investment deals in Africa country report: Ethiopia. Retrieved from www.oaklandinstitute.org dated 23/4/13.

Pankhurst A (2001). "Resource management institutions in post- conflict situations: lessons from *yegof* state forest, south Wello zone, Amhara Region, Ethiopia." In Pankhurst A (edt.) Natural Resource Management in Ethiopia, proceedings of the workshop organized by Forum for Social Studies in collaboration with the University of Sussex; Addis Ababa, Ethiopia.

Reusing M (2000). Change detection of natural high forests in Ethiopia using remote sensing and GIS techniques. Int. Arch. Photogram. Remote Sensing 33(B7):1253-1256.

Sahle GK (1984). An ecological study of the vegetation on the eastern escarpment of Eritrea, Ethiopia. A Thesis presented to the school of graduate studies, Addis Ababa University; Addis Ababa, Ethiopia.

Sisay N (2008). "Ethiopian government efforts to increase forest cover: a policy oriented discussion paper." In Bane J, Sisay N, Alemu M,

and Randall BP (edts.) Polices to increase forest resources of Ethiopia, Proceedings of a policy workshop organized by Environmental Economics Policy Forum for Ethiopia (EEPFE) and Ethiopian Development Research Institute (EDRI): Addis Ababa, Ethiopia.

Tarekegn Y (2001). “Enclosing or 'individualizing' the 'commons'? the implementation of two user-rights approaches to 'communal' areas management in post-Derg Northern Ethiopia”**,** in (edt.) Pankhurst, A, Natural Resource Management in Ethiopia. Addis Ababa, Ethiopia.

Teshome W, Rangsipaht S, Chanprasert W (2011). Natural resource conservation practices of resettlers in the new resettlement areas of Amhara region, Ethiopia. Kasetsart J. Soc. Sci. 32:297-307.

Tsegaye T (2006). An overview of the forest ecosystems of Ethiopia: functions, trends and future directions In Seyoum Mengistu and Stoop, C. (edt.); Environment for survival taking stock of Ethiopia’s environment proceedings of the first green forum conference held in Addis Ababa, Ethiopia. pp. 18-34.

United Nations/UN/ (1993). Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, vol. I, Resolutions Adopted by the Conference No.E.93.I.8 and corrigendum.

Yeraswork A (2001). “Overview of natural resources management in Ethiopia and policy implications”. In Pankhurst A (*edt) Natural* Resource Management in Ethiopia, proceedings of the workshop organized by Forum for Social Studies in collaboration with the University of Sussex; Addis Ababa, Ethiopia.

Yitebitu M, Zewdu E, Sisay N (2012). Ethiopian forest resources: current status and future management options in view of access to carbon finances. Prepared for the Ethiopia climate research and networking and UNDP. Addis Ababa; Ethiopia. pp. 15-20.

academicJournals

Vol. 6(2), pp. 132-137, February 2014
DOI: 10.5897/IJBC2013.0663
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

A comparative study of fish species composition in two spatially isolated nature reserves, Jiangxi, China

Mao-Lin Hu[1]*, Jian-Ming Zhang[2], Hui-Ming Zhou[3], Qi Hua[4], Zhi-Qiang Wu[5] and Fei Li[6]

[1]School of Life Sciences and Food Engineering, Nanchang University, Nanchang, Jiangxi, China
[2]Ganzhou Fisheries Research Institute, Ganzhou, Jiangxi, China.
[3]Jiangxi Fisheries Research Institute, Nanchang, Jiangxi, China.
[4]Jiangxi Aquaculture Technology Extending Stations, Nanchang, Jiangxi, China.
[5]College of Environmental Sciences and Engineering, Guilin University of Technology, Guilin, Guangxi, China.
[6]Jiangxi Entry-Exit Inspections and Quarantine Bureau, Nanchang, Jiangxi, China.

Accepted 6 January, 2014

The ichthyofauna of mountain streams in the Danzhangshan Nature Reserve (DNR) and the Raoheyuan Nature Reserve (RNR) was investigated during 2008. A total of 385 samples were collected and classified into seven families and 14 species from the two nature reserves. There were 12 species belonging to seven families in the RNR, while eight species from four families were collected in the DNR. Overall, six species were found to be endemic to China, representing five families. The relative abundance of endemic species to China was higher in the RNR than in the DNR. Current threats to conservation of fishes in both nature reserves were reviewed and management solutions are suggested.

Key words: Fish, species, diversity, conservation, nature reserve, China.

INTRODUCTION

Jiangxi Province (between 113°34¢36²-118°28¢36²E and 24°29¢14²-30°04¢41²N) is located in south China, and to south of the middle and lower reaches of Yangtze River. Poyang Lake, the largest freshwater body in China is located in the north of Jiangxi Province. The area immediately surrounding Poyang Lake consists of low-lying alluvial plains prone to flooding. Mountains close to the boundaries of Jiangxi Province surround this region and all the five major rivers in the province (Ganjiang River, Xinjiang River, Fuhe River, Raohe River and Xiuhe River) flow into the Poyang Lake. The drainage to Poyang Lake is a narrow outlet named Hukou, which flows into the Yangtze River and marks the northern border of the province. The sources of the rivers in Jiangxi Province are located in the surrounding mountains. Of a total of 220 recorded freshwater fish species throughout Jiangxi Province, about 131 species (59.5%) are believed to be endemic, many present in the mountain regions (Huang et al., 2011). Protected areas such as nature reserves could play an important role in conservation of freshwater fishes within Jiangxi Province, but there is a need to better identify the conservation value of these areas in relation to biogeographical diversity of fishes and the factors impacting on fish communities.

Worldwide, freshwater fishes are the most diverse of all vertebrate groups, but are also the most highly threatened (Duncan and Lockwood, 2001). Most mountain streams in the Danzhangshan Nature Reserve (DNR) and the Raoheyuan Nature Reserve (RNR), both located in Jiangxi Province, are shallow and the hydrology of most headwater streams has been modified

*Corresponding author. E-mail: humaolin@ncu.edu.cn. Tel: +86-791-85256500.

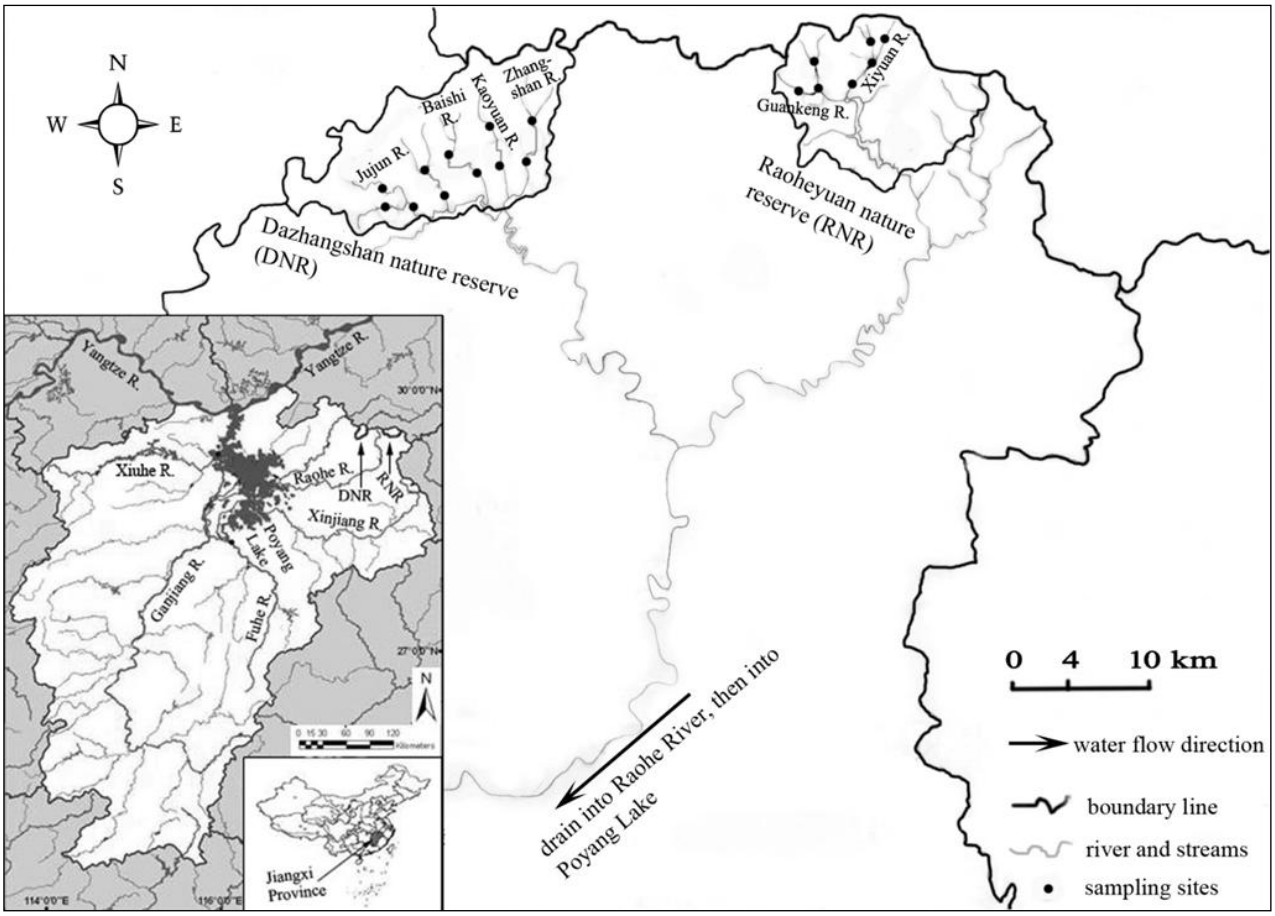


Figure 1. Map showing location of the two nature reserves and sampling sites.

by farming and irrigation of surrounding land. Recently, numerous anthropogenic disturbances, such as clear-cuts, small dams, road construction, fires and mining, have triggered physico-chemical alterations in the mountain streams (SFIPI, 2005a, b).

At present, there have been several notable surveys of the flora and fauna within the two nature reserves. These studies include surveys of the bird, amphibia, reptile, and insect faunas and flora (SFIPI, 2005a, b). However, until this work there have been no studies on the distribution and abundance of fish species in both nature reserves. The aims of the present study were: (1) to characterize the species composition of the fish fauna and their distribution in both nature reserves; (2) to review the main threats over fish biodiversity, and (3) to establish some recommendations to the conservation of the fish fauna.

MATERIALS AND METHODS

Study area

The DNR (total area: 153.70 km^2, altitude: 1629.8 m) and RNR (total area: 115.96 km^2, altitude: 1468.5 m) are located in the northeastern Jiangxi Province (Figure 1). Both reserve areas present humid subtropical climate and belong to the forest ecological nature reserve for the conservation of evergreen broad-leaved forest ecological system and biodiversity (SFIPI, 2005a, b). Most mountain streams flow into the Le'an River which drains into the Raohe River (Figure 1).

Study site

Three-monthly samples were made at 11 sites in the DNR and seven sites in the RNR during 2008 (Figure 1). At each sampling site, the GPS position and altitude were recorded using a Garmin GPS map 76Cx. Physico-chemical parameters (water temperature, dissolved oxygen, pH, stream width and water depth) were measured. Water temperature, pH and dissolved oxygen levels were measured with a hand-held YSI multi-meter before entering the water to minimize disturbance. In addition, the habitat types were recorded for all sites.

Fish survey

All the stations were characterized by shallow water depths, narrow channel widths, and relatively fast water currents flowing over boulder substrate. At each site, samples were collected using an electrofishing device consisting of two copper electrodes on

Table 1. Key catchment characteristics within the sampled areas across the two nature reserves, including altitude and number of sampling sites, stream width and water depth, and habitat types.

Catchment	Nature reserve	Altitude (m)	Depth (m)	Width (m)	Number of sites surveyed	Habitat description
Xiyuan River (XR)	RNR	290-320	0.7-2.5	3.0-10.0	4	Slow flowing and slightly turbid water with gravel and sandy substrate, river shaded by riparian vegetation.
Guankeng River (GR)	RNR	295-356	0.6-2.0	4.0-11.0	3	Slow flowing and slightly turbid water, gravel and sandy bottom, shaded by riparian vegetation.
Baishi River (BR)	DNR	254-299	0.4-0.8	1.5-4.0	2	Fast flowing and clear water with rocky and pebbles sediment, shaded by forest canopy
Jujun River (JR)	DNR	245-312	0.3-0.9	1.5-5.0	5	Fast flowing and clear water with gravel, sandy and pebbles sediment, shaded by forest canopy.
Zhangshan River (ZR)	DNR	881-928	0.2-1.0	1.0-3.5	2	Fast flowing and clear water with gravel and rocky substrate, shaded by forest canopy.
Kaoyuan River (KR)	DNR	258-306	0.3-1.2	2.0-4.0	2	Fast flowing and clear water with rocky and sandy substrate, shaded by forest canopy.

wooden handles, powered by a 500-watt portable AC generator. Stunned fish were collected using dip nets or caught by hand. A cast net (mesh 5×5 mm; $\pi \times 0.6^2$ m = 1.13 m^2) was also used in shallow pools of the stream system. Approximately, 100 m of stream segment, typically comprising pool, run and riffle habitats, was sampled at each site. Collected specimens were preserved in 10% formalin solution until counting, after which they were stored in 5% formalin solution. All specimens were identified according to Zhu (1995), Chen (1998), Chu et al. (1999) and Yue (2000).

Data analyses

The relative abundance of each species at each sampling site was estimated by: $P_{jk} = N_{jk} / N_k$, where N_{jk} = the number of species j collected in site k; N_k = the total number of all fish collected in site k. To assess specific differences in the two nature reserves, we calculated richness, evenness, diversity indices and Bray-Curtis dissimilarities index based on species and abundance data from each site using PRIMER 5 software.

RESULTS AND DISCUSSION

Physical and chemical parameters

Physico-chemical characteristics were similar among all studied sites in the two nature reserve (Table 1). Most of the surveyed sampling sites were composed of sandy, gravel and pebbles substrates and the banks were lined by boulders and rocks. Shallow pools and riffles alternated in the segments studied. Generally, the rivers were speedy flowing. The water was clear, and shore vegetation was forest canopy. This appearance is typical of undisturbed forest stream at higher altitudes.

The mean (± SE) water temperature was 12.6 ± 5.2°C in the DNR and 15.8 ± 2.6°C in the RNR. Water temperature ranged from 9.6 to 15.2°C in the DNR and 11.6 to 19.2°C in the RNR. All sites in the two nature reserves were fully saturated with dissolved oxygen (mean ± SE, 9.2 ± 1.8 $mg \cdot L^{-1}$ in the DNR; 8.6 ± 1.2 $mg \cdot L^{-1}$ in the RNR). The high DO could be attributed to low water temperature and high water speed. Site average pHs were between 5.8 to 7.6 (mean ± SE, 6.8 ± 0.9) in both nature reserves.

Fish fauna in the DNR and the RNR

A total of 385 fish were collected and classified into 14 species and seven families at both nature reserves (Table 2). 118 fish belonging to eight species and four families were collected in the DNR, while a total of 267 fish were collected and classified into 12 species and seven families in the RNR (Table 2).

At both nature reserves, more than half of fish species (eight species, 57.14% of the total number of fish species collected) belonged to the family Cyprinidae (*Acrossocheilus parallens*, *Carassius auratus auratus*, *Opsariichthys bidens*, *Zacco platypus*, *Abbottina rivularis*, *Gnathopogon imberbis*, *Rhodeus ocellatus ocellatus* and *Rhynchocypris oxycephalus*). The following families have been represented by one species per family: Cobitidae (*Misgurnus anguillicaudatus*), Homalopteridae (*Vanmanenia pingchowensis*), Bagridae (*Pseudobagrus ondon*), Odontobutidae (*Odontobutis sinensis*), Gobiidae (*Rhinogobius cliffordpopei*) and Synbranchidae (*Monopterus albus*).

In the DNR, Cyprinidae was represented by five species (62.50% of the total fish species collected in this zone) and the 96 specimens corresponded to 81.36% of the total abundance. In the RNR we collected six species belonging to the family Cyprinidae (50.00% of the total fish species collected in this reserve) and the 205

Table 2. Ichthyofauna recorded in the two nature reserves.

Fish species	RNR		DNR				Total
	XR	GR	BR	JR	ZR	KR	
Cyprinidae							
Acrossocheilus parallens (Nichols, 1931)*	48	35		2		6	91
Carassius auratus auratus (Linnaeus, 1758)	1	5					6
Opsariichthys bidens Günther, 1873	59	21		1			81
Zacco platypus (Temminck & Schlegel, 1846)				1			1
Abbottina rivularis (Basilewsky, 1855)					6		6
Gnathopogon imberbis (Sauvage & Dabry de Thiersant, 1874) *	4	6					10
Rhodeus ocellatus ocellatus (Kner, 1866)		1					1
Rhynchocypris oxycephalus (Sauvage & Dabry de Thiersant, 1874)		25	56		24		105
Cobitidae							
Misgurnus anguillicaudatus (Cantor, 1842)	17	2		3			22
Homalopteridae							
Vanmanenia pingchowensis (Fang, 1935) *	11	1					12
Bagridae							
Pseudobagrus ondon (Shaw, 1930)*	2	3					5
Odontobutidae							
Odontobutis sinensis Wu, (Chen and Chong, 2002)*	2	12			15		29
Gobiidae							
Rhinogobius cliffordpopei (Nichols, 1925) *	10			1		3	14
Synbranchidae							
Monopterus albus (Zuiew, 1793)		2					2
Number of individuals	154	113	56	8	45	9	385

*Endemic to China (Huang et al., 2011; FishBase: www.fishbase.org).

individuals obtained represented 76.78% of the total abundance.

The dominancy of the species in the DNR was *Rhynchocypris oxycephalus* [relative abundance (RA), 67.80%], *Odontobutis sinensis* (RA, 12.71%), *Acrossocheilus parallens* (RA, 6.78%), *Abbottina rivularis* (RA, 5.08%) and *Rhinogobius cliffordpopei* (RA, 3.39%). In the RNR, the dominancy was as follow: *Acrossocheilus parallens* (RA, 31.09%), *Opsariichthys bidens* (RA, 29.96%), *Rhynchocypris oxycephalus* (RA, 9.36%), *Misgurnus anguillicaudatus* (RA, 7.12%), *Odontobutis sinensis* (RA, 5.24%), *Vanmanenia pingchowensis* (RA, 4.49%), *Gnathopogon imberbis* and *Rhinogobius cliffordpopei* (RA, 3.75% respectively), *Carassius auratus auratus* (RA, 2.25%) and *Pseudobagrus ondon* (RA, 1.87%).

Overall, six species were found to be endemic to China and endemism of stream fish in both nature reserves combined was 42.86%. Relative abundance of endemic species to China was higher in the RNR (50.00%) than that in the DNR (37.50%). Endemic fishes were classified into three species and three families in the DNR, and six species and five families in the RNR. The dominant family of endemic fishes was Cyprinidae [101 individuals, relative abundance of endemics (RAE) 62.73%, two species] and the subdominant families were Odontobutidae (29 individuals, RAE 18.01%; one species), Gobiidae (14 individuals, RAE 8.70%; one species), Homalopteridae (12 individuals, RAE 7.45%; one species) and Bagridae (5 individuals, RAE 3.11%; one species). The most common endemic species to China was *Acrossocheilus parallens*, followed in order of abundance by *Odontobutis sinensis*, *Vanmanenia pingchowensis*, *Gnathopogon imberbis*, *Rhinogobius cliffordpopei* and *Pseudobagrus ondon* in the RNR. In the DNR, the endemic species were *Odontobutis sinensis*, the most frequent followed by *Acrossocheilus parallens* and *Rhinogobius cliffordpopei*.

The ecological indices for the two nature reserves showed that in the RNR, there were comparatively higher species richness, evenness and diversity. The Bray-Curtis dissimilarities index for the two nature reserves was 54.64% (Table 3).

Factors favoring diversity and endemism

The results of the present field studies on both nature reserves show that a total of 14 native species belonging to seven families were collected or found to be distributed in mountain streams. Overall, six species belonging to five families were found to be endemic to China. The

Table 3. The comparative ecological indices for the two nature reserves.

Parameter	DNR	RNR
Species count (S)	8	12
Number of individuals (n)	118	267
Common species (RA)	*Acrossocheilus parallens* (6.78%)	*Acrossocheilus parallens* (31.09%)
	Opsariichthys bidens (0.85%)	*Opsariichthys bidens* (29.96%)
	Rhynchocypris oxycephalus (67.80%)	*Rhynchocypris oxycephalus* (9.36%)
	Misgurnus anguillicaudatus (2.54%)	*Misgurnus anguillicaudatus* (7.12%)
	Odontobutis sinensis (12.71%)	*Odontobutis sinensis* (5.24%)
	Rhinogobius cliffordpopei (3.39%)	*Rhinogobius cliffordpopei* (3.75%)
Common family (S)	Cyprinidae (5)	Cyprinidae (6)
	Cobitidae (1)	Cobitidae (1)
	Odontobutidae (1)	Odontobutidae (1)
	Gobiidae (1)	Gobiidae (1)
Richness index		
Margalef (D)	1.467	1.969
Evenness indices		
Shannon's (H)	1.149	1.892
Pielou's (E)	0.552	0.761
Simpson's (λ)	0.485	0.209
Diversity indexes		
Hill's number, N_1	3.154	6.630
Hill's number, N_2	2.062	4.791
Bray-Curtis dissimilarities index	54.64%	

more abundant species or endemic species collected from both nature reserves belonged to the family Cyprinidae. Huang et al. (2011) stated that Cyprinidae is the most species-rich or endemic species-rich family recorded throughout Jiangxi Province. The fish diversity was comparatively higher in the RNR than in the DNR. The hydrological characteristics such as water depth and current, shoreline slopes and bottom substrates were relatively different. Mountain stream was wider in the RNR than in the DNR. The substrate in the RNR was formed mainly of sandy-gravel, whereas in the DNR, the substrate consisted mainly of rocky-pebbles which are very unstable. Several dense aquatic vegetations in the RNR have created small unique pool habitats. According to Zakaria et al. (1999), this condition could be a more suitable habitat for higher species diversity and richness and most fishes were recorded in a channel stream part of a wide river where the water is deeper and slower. Therefore, the caught fishes were mostly in the slow water area, particularly amongst the aquatic vegetation.

It is interesting to note that *R. oxycephalus* was dominant in the DNR and subdominant in the RNR. The presence of this representative cold water species of the Holarctic Region in China, which is restricted to mountain streams in Jiangxi Province (except for the Xunwushui River and the south of Jiangxi Province), may be related to the effect of Quaternary glaciations (Zhang and Chen, 1997). Fish of the genus *Rhynchocypris* tend to be distributed in the north of China whilst *R. oxycephalus* is found south as far as the Minjiang River in Fujian Province. It had suggested that the alternating Quaternary glacial and interglacial periods moved *R. oxycephalus* to the south where the species had survived in the small mountain streams where the water is cold (Huang et al., 2011).

Current threats and conservation

During recent decades, streams and rivers in China have been drastically modified because of agricultural activities, drinking water supplies and the construction of multi-purpose dams, artificial reservoirs, levees, and weirs. These physical alterations and other human influences, such as road construction and deforestation have accelerated eutrophication (Fu et al., 2003). For example, Duanxin Reservoir was built in the RNR on December 1975 and Qinghua Reservoir was built on the boundary area of the DNR in April 1990. These factors strongly diminished effective migration for those species moving between different stream habitats. Small and fast-flowing streams have often been changed to large slow-flowing streams. This change would make the organisms become restricted to mountainous areas and to be replaced by other beings adapted to slow-flowing streams (Hu et al., 2009). In addition, some people catch fish for

food in the mountain streams of both nature reserves using rotenone and other poisons which usually are used to exterminate snails. This kind of fishing not only contributes to reduce fish biodiversity but is also harmful to human health.

Therefore, the primary objective for successful conservation of the freshwater ichthyofaunal diversity in both nature reserves must be to develop effective controls and management practices that enable life cycle success, dispersal and population maintenance within stream systems. It is necessary to improve effective fish passage facilities in order to enhance the connectivity of streams for fish dispersal and migration. Fishing activities in both nature reserves, especially using rotenone and other poisons must be strictly prohibited. The present work agrees with the statement long-term management and conservation of the fish fauna of nature reserves and other protected areas in Jiangxi Province will require good bench-mark sites and a long-term monitoring protocol (Jang et al., 2003).

ACKNOWLEDGMENTS

The study was funded by National Natural Science Foundation of China (No. 31360118), and Natural Science Foundation of Jiangxi Province (No. 20122BAB214020), and Education Foundation of Jiangxi Province (No. GJJ13090). We are grateful to the staff of Wuyuan Forestry Bureau for their help provided during the survey.

REFERENCES

Chen YY (1998). Fauna Sinica: Osteichthyes Cypriniformes II. Science Press, Beijing. pp. 1-531.

Chu XL, Zheng BS, Dai DY (1999). Fauna Sinica: Osteichthyes Siluriformes. Science Press, Beijing. pp. 1-230.

Duncan JR, Lockwood JL (2001). Extinction in a field of bullets: a search for the causes in the decline of the world's freshwater fishes. Biol. Conserv. 102: 97-105.

Fu CZ, Wu JH, Chen JK, Wu QH, Lei GC (2003). Freshwater fish biodiversity in the Yangtze River basin of China: patterns, threats and conservation. Biodivers. Conserv. 12:1649-1685.

Hu ML, Wu ZQ, Liu YL (2009). The fish fauna of mountain streams in the Guanshan National Nature Reserve, Jiangxi, China. Environ. Biol. Fish 86:23-27.

Huang LL, Wu ZQ, Li JH (2011). Fish fauna, biogeography and conservation of freshwater fish in Poyang Lake Basin, China. Environ. Biol. Fish DOI: 10.1007/s10641-011-9806-2.

Jang MH, Martyn CL, Joo GJ (2003). The fish fauna of mountain streams in South Korean national parks and its significance to conservation of regional freshwater fish biodiversity. Biol. Conserv. 114:115-126.

Shangrao Forest Inventory and Planning Institution (SFIPI) (2005a). Comprehensive survey of Jiangxi Dazhangshan nature reserve. Wuyuan Forestry Bureau, Shangrao. pp. 1-123.

Shangrao Forest Inventory and Planning Institution (SFIPI) (2005b). Comprehensive survey of Jiangxi Raoheyuan nature reserve. Wuyuan Forestry Bureau, Shangrao. pp. 1-135.

Yue PQ (2000). Fauna Sinica: Osteichthyes Cypriniformes Ш. Science Press, Beijing. pp. 1-661.

Zakaria R, Mansor M, Ali AB (1999). Swamp-riverine tropical fish population: a comparative study of two spatially isolated freshwater ecosystems in Peninsular Malaysia. Wetl. Ecol. Manage. 6: 261-268.

Zhang E, Chen YY (1997). Fish fauna in Northeastern Jiangxi province with a discussion on the zoogeographical division of east China. Acta Hydrobiologia Sinica 21(3):254-261.

Zhu SQ (1995). The synopsis of freshwater fishes of China. Jiangsu Science and Technology Press, Nanjing. pp. 1-549.

academicJournals

Vol. 6(2), pp. 138-147, February 2014
DOI: 10.5897/IJBC2013.0655
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Factors affecting attitudes of local people toward the red-billed Quelea (*Quelea quelea*) in Kondoa District, Tanzania

Flora Manyama[1,2]*, Julius W. Nyahongo[2] and Eivin Røskaft[1]

[1]Department of Biology, Norwegian University of Science and Technology, Realfagbygget, N-7491 Trondheim, Norway.
[2]School of Biological Sciences, College of Natural and Mathematical Sciences, The University of Dodoma, P. O. Box 259, Dodoma, Tanzania.

Accepted 16 January, 2014

Interactions between humans and red-billed Queleas (*Quelea quelea*) in Kondoa District, central Tanzania, have shaped the attitudes of the local inhabitants toward these birds. These birds are considered as serious pest because they consume small grain cereal crops. The red-billed Queleas are caught and consumed as food by local communities. Harvested birds are also sold at bus stops to passengers, as well as to local villagers, as a source of household income. This study aimed to evaluate the influence of differential costs and benefits of the red-billed Quelea, as well as the socio-economic factors (education level, gender, age and economic activity) that might shape the attitudes of the local inhabitants of Kondoa. To explore their attitudes, a questionnaire survey was randomly conducted among 360 households in six villages from June to August 2012. Most of the inhabitants who incurred costs of crop damage exhibited negative attitudes toward the red-billed Quelea, despite the benefits obtained from them. In contrast, those who benefitted from harvested Quelea birds exhibited positive attitudes towards the red-billed Quelea. The most important socio-economic factors influencing both positive and negative attitudes were education and gender. In contrast, economic activity only influenced negative attitudes. To change negative attitudes towards the birds; practical, economical and applicable solutions for the Quelea pest problem are needed while considering the future conservation of the species in the area.

Key words: Attitudes, costs, benefits, red-billed Quelea, socio-economic factors, local inhabitants, Kondoa-Tanzania.

INTRODUCTION

The interactions between humans and wildlife have led to both positive and negative attitudes toward conservational objectives. The positive attitudes are predominantly associated with wildlife-derived benefits, whereas the negative attitudes are created by wildlife-related costs, including the opportunity costs of conservation (Gereta and Røskaft, 2010; Røskaft, 2012; Røskaft et al., 2007).

The growth of human population, together with increased human activities have been described as major challenges in wildlife conservation (Dar et al., 2009; Holmern et al., 2007; Kideghesho et al., 2007; Packer et al., 2005; Røskaft, 2012). This is largely due to increased interactions between humans and wildlife, which, in turn, generates conflicts as a result of competition for natural resources (Hanley et al., 2010; Treves and Karanth,

*Corresponding author. E-mail: modalflom@yahoo.com

2003; Treves et al., 2006). A number of species are regarded as problem animals because of their conflicts with humans in terms of crop damage, livestock depredation and human attacks (Ikanda, 2010; Løe and Røskaft, 2004; Packer et al., 2005). Such conflicts significantly affect the survival of both humans, as well as wildlife, either directly or indirectly through retaliatory killings of animals and habitat loss (Ikanda and Packer, 2008; Løe and Røskaft, 2004). It also creates negative attitudes for people, particularly when wildlife-related costs are increased compared to wildlife-related benefits and when compensation schemes are lacking (Holmern et al., 2007; Kideghesho et al., 2007; Nyahongo, 2010).

Most countries including Tanzania have failed to fully compensate local inhabitants on wildlife-related costs due to lack of sufficient funding, as well as to difficulties in evaluating the exact costs and claims (Gereta and Røskaft, 2010; Hemson et al., 2009; Løe and Røskaft, 2004; Mfunda and Røskaft, 2011). However, compensation does not guarantee positive attitudes toward problem animals (Naughton-Treves et al., 2003; Røskaft et al., 2007). Despite the problems that they cause to people, more efforts are used to conserve the so-called problem animals because of different values attached to them, either directly or indirectly, including ethical values. However, the achievements of such efforts require support from people, which is highly influenced by their attitudes toward conservation (Røskaft et al., 2007; Treves and Karanth, 2003). Generally, there is a need to improve agriculture to enhance the livelihoods of poor people in rural areas, and one such improvement is the control of the Quelea pest problem in Kondoa. The process of changing the attitudes of the people of Kondoa follows only after the identification of such attitudes, the analysis of the problems associated with negative attitudes and a solution to those problems.

Psychologists define an attitude as a learned tendency used to evaluate things in a specific way. Such evaluations are often positive or negative, but they can also be uncertain due to mixed feelings regarding a parti-cular situation (Kideghesho et al., 2007). Attitudes can influence our decisions, guide our behaviours and impact what we selectively remember. Attitudinal studies can also help to evaluate public understanding, acceptance of wildlife and the impacts of conservation programs despite the negative factors that can create negative attitudes (Dar et al., 2009; Kaltenborn et al., 2006; Kideghesho et al., 2007; Røskaft et al., 2007). Generally, attitudes toward the conservation of wildlife are mostly influenced by the benefits that people gain, as well as the negative consequences that they acquire (Gereta and Røskaft 2010; Gillingham and Lee, 1999; Hemson et al. 2009; Kaltenborn et al., 2006; Røskaft 2012; Røskaft et al., 2007).

The red-billed Quelea is among the major pests of small grain cereal crops throughout semi-arid areas of sub-Saharan Africa (Cheke, 2003; Dallimer and Jones, 2002; Elliott, 1979; Mullie, 2000; Ruelle and Bruggers, 1982). This is most likely due to the expansion of their distribution range and population size from 10 to 100 times since the 1970s as a result of the increased availability of food sources, including cereal crops (Elliott and Bright, 2007; Markula et al., 2009). Probably due to expansion of agricultural production there is human population growth. The inhabitants of Kondoa use traditional ways to illegally harvest the birds to reduce the red-billed Quelea populations. Such a strategy might potentially reduce the cost of chemical control and its associated direct and indirect harmful effects to humans, other non-targeted organisms and to the environment (Cheke, 2003; Cheke et al., 2012; Elliott and Bright, 2007; Mullie, 2000). This approach appears to be the best of different suitable control measures if well organised and is being considered in policies and legal proceedings (Elliott and Bright, 2007). Understanding attitudes of the Kondoan people towards the red-billed Quelea can help to provide a new basis for management actions and guide the policy and management decisions involved in the design, implementation and evaluation of the conservation and management of Quelea populations.

The aim of this study was to assess how the local inhabitants of the Kondoa District assess the costs and benefits of having the red-billed Quelea in their vicinity. We tested the influence of the costs and benefits of the red-billed Quelea in terms of the attitudes of the local inhabitants. The hypothesis tested was that the inhabitants who incurred crop damage costs would exhibit negative attitudes toward the red-billed quelea, whereas those who benefitted from the bird would exhibit positive attitudes. The influence of socio-economic factors on the human attitudes toward the red-billed Quelea in Kondoa was also evaluated. Lastly, we propose management actions that might help to control Quelea populations from crop damage without spraying chemicals which are unselective.

METHODOLOGY

Study species

The red-billed Quelea (Quelea quelea)

The red-billed Quelea is a small passerine bird that belongs to the Ploceidae family. The red-billed Quelea lives in enormous populations of up to 12 million birds and is most likely the most abundant wild bird in the world (de Mey et al., 2012). Breeding colonies can comprise up to 30 million individuals and can cover more than 100 ha with approximately 3,000 to 30,000 nests per ha (Allan, 1996; Cheke et al., 2007; de Mey et al., 2012; Elliott and Bright, 2007; Elliott, 2006; Hartley and Mundy, 1999; Markula et al., 2009; Ruelle and Bruggers, 1982). Such large populations exist due to the high availability of their food types including cereal crops, high fecundity levels as well as their ability to follow seasonal rainfall patterns into areas that have received rainfall for feeding and breeding (Elliott, 1979, 1990; 2006; Mullie, 2000). However, it

is not clear whether these birds can continue to survive in such huge numbers for the coming centuries, despite their fecundity. The major challenge currently facing the red-billed Quelea is a conflict with farmers due to crop damage, which results in the large numbers of Quelea killings every year as a pest control measure.

The red-billed Quelea is adapted to the semi-arid woodland and grassland habitats of the dry tropical African savannah at altitudes below 2000 m (Elliott and Bright, 2007; Hartley and Mundy, 1999; Markula et al., 2009). These birds are generally granivorous, feeding on small grains, seeds of native annual grasses and cultivated cereal crops such as sorghum, millet, rice, wheat, oats, maize, sunflower, and barley (Allan, 1996; Cheke et al., 2007; Elliott, 1979, 2006; Hartley and Mundy, 1999; Markula et al., 2009; Ruelle and Bruggers, 1982), it is regarded as an agricultural pest with a significant impact on crop yield (Allan, 1996; Elliott, 2006). The Quelea pest problem is a serious threat to the livelihoods of farmers growing small grain cereal crops in Central, Eastern and Southern Africa, and particularly in Tanzania, Zimbabwe, Botswana and South Africa (Cheke et al., 2012). Tanzania is among the countries with the largest populations of the red-billed Quelea, with an estimated post-breeding population of 124 million birds (Elliott, 2006). The Kondoa District in Central Tanzania is one of the places with such a high abundance of Quelea (Allan, 1996) and the local inhabitants face the problem of crop damage by quelea birds. Apart from local initiatives, the government also raises efforts to control the Quelea pest problem by spraying chemicals (queletox) from aircrafts into Quelea breeding colonies and night roosts (Cheke et al., 2012).

Study area

The study was conducted in six villages located within the Kondoa District of the Dodoma Region in Central Tanzania (Figure 1). Dodoma is a semi-arid region with an altitude ranging from 1200 to 1500 m above sea level.The mean maximum and minimum temperatures are 31 and 18°C, respectively. The mean annual rainfall varies between 600 and 1000 mm, which falls between November and April (URT, 2013a). The Kondoa District has a total population exceeding 260,000 people (URT, 2013b) with a population growth rate of two percent annually and a total area of 13,210 km^2 extending from 4° 30'S to 5° 36'S and 35° 10'E to 36° 27'E (Figure 1).

The six villages comprise an area of 360.5 km^2 and a total population of more than 15,000 people (URT, 2013b), with an average household size of five people. The majority of people are mostly agro-pastoralists, cultivating crops and keeping livestock for subsistence. The main types of food crops cultivated that are into conflict with the red-billed Quelea are pearl millet (*Pennisetum glaucum)*, and sorghum (*Sorghum bicolor)*.

Despite the fact that the majority of people are agro-pastoralists, their economy is supplemented with charcoal production and local businesses that trap Quelea birds for sale to passengers at bus stops and in the streets for household consumption. The majority of the harvested birds are sold at a price ranged between Tsh. 100 and 300 (US $ 0.06 - 0.18), per bird when fried, Tsh. 100 (US $ 0.06) per three birds and Tsh 50 (US $ 0.03) per bird when sold as fresh meat. These villages were selected as study sites because of the increased interactions between local people and the red-billed Quelea in terms of crop damage and illegal harvesting of the red-billed Quelea for household consumption.

Data collection

Face-to-face interviews were conducted by means of a questionnaire that assessed the human attitudes toward the red-billed Quelea from June to August, 2012. The purpose of the interview was to ascertain the attitudes of the local inhabitants toward the red-billed Quelea and their perceptions of how this bird damages their crops. In addition, we wanted to record the benefits derived from the harvested Quelea birds. To assess the proper identification of the study species, the respondents were asked whether they knew the species prior to the interview. This was done by asking questions that require the respondent to identify the key observable features of the red-billed Quelea. Data were collected at the household level through formal, semi-structured (both close and open ended) questionnaire surveys to different groups of people aged 18 years and above. The survey involved respondents from a stratified random selected sample of 360 households drawn from the six study villages; Kelema Balai (n = 60), Paranga (n = 60), Kelema kuu (n = 60), Isini (n = 60), Cheku (n = 60) and Sori (n = 60) (Figure 1). The purpose of the random sampling was to include as many different socio-economic conditions as possible.

A household was defined as a person or group of people living together in the same compound, who share some common living arrangements and are responsible to the same household head (URT, 2013b). In the household, the head of the family was selected for the interview, and when the head was absent, any adult of at least 18 years age was selected. The main collected information included the respondents' age, sex, education level, household size and economic activities. The information regarding the costs and benefits of the red-billed Quelea to local communities and people's attitudes toward the bird were collected from attitude-testing questions.

The qualitative data were collected through informal interviews, focused group discussions and literature reviews to supplement the quantitative data in terms of the discussion-related information. The main stakeholders for the interviews and group discussions were the local inhabitants, village leaders and the staff of the local government at the Kondoa District specifically from three departments (natural resources, agriculture and planning) because of their interactions with Quelea-related matters and local communities within the area. The key words for the discussions were the costs and benefits of Quelea to local communities, Quelea abundance and distribution, as well as the Quelea pest management programs.

Data analyses

Chi-square tests and binary logistic regression analyses were applied to test the differences between the dependent, as well as the independent variables with a significance level of $p < 0.05$. Almost all of the data were non-parametric. Thus, most of the analyses were performed using non-parametric descriptive statistics and statistical tests.

The Pearson's χ^2 tests were used to test the association between the positive attitudes and Quelea benefits and the negative attitudes and Quelea-related costs. Binary logistic regression analyses were used to test the influence of socio-economic factors and their interactions as independent variables with the positive and negative attitudes of Kondoan people towards the red-billed Quelea as dependent variables. Data analyses were performed using SPSS (the Statistical Package for Social Sciences, Version 20).

RESULTS

Demographic characteristics of respondents

The general characteristics of 360 respondents who were selected from households in six villages within Kondoa District were; 53.6% males and 46.4% females, 37.2% were 18 - 36 years, 40.3% were 37 - 54 years and 22.5%

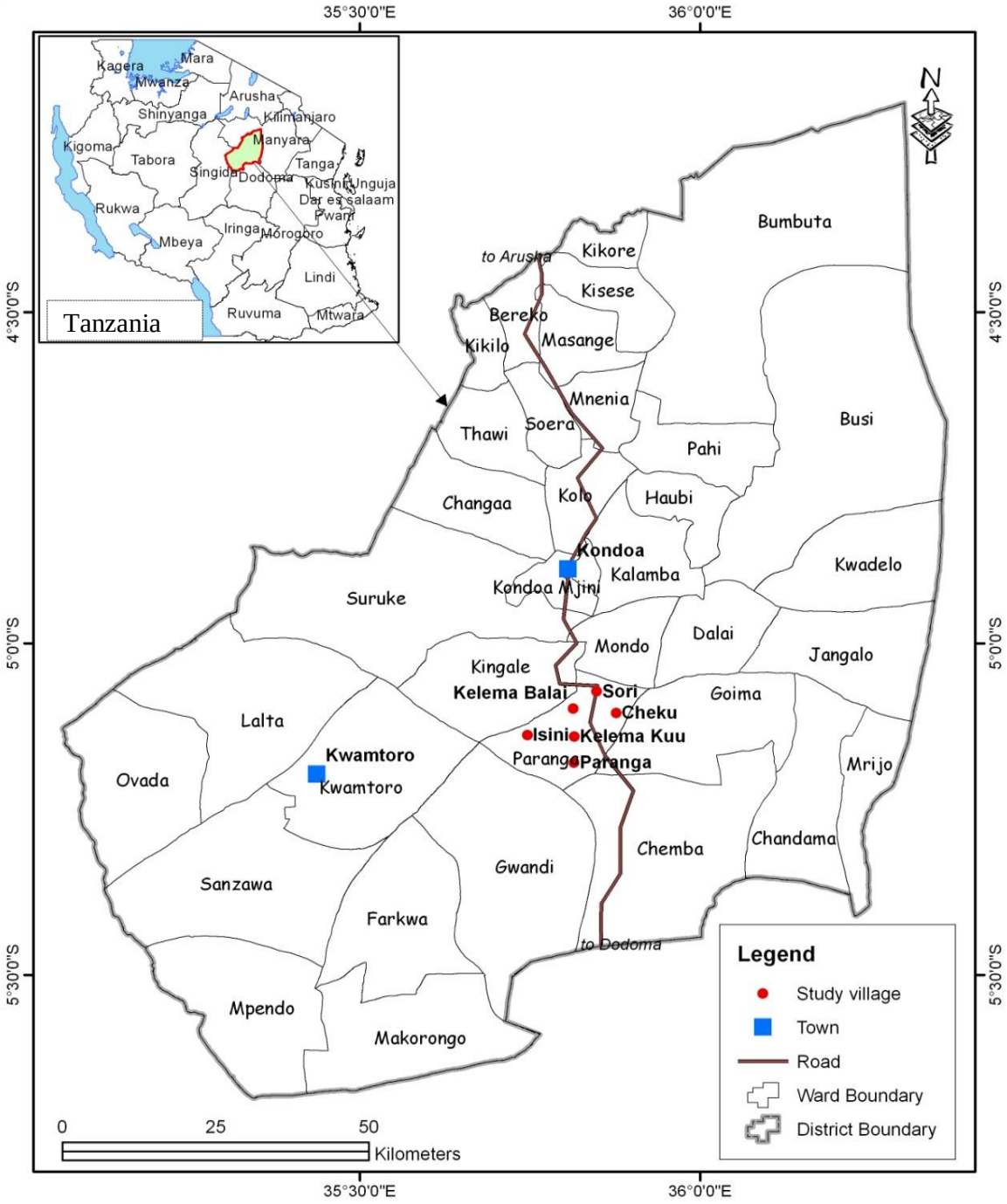


Figure 1. Map of the study area - the Kondoa District in Central Tanzania showing the six study villages (red dots).

were above 55 years. Two third (70%) of the residents had primary school education, while 17.2% were illiterate and 12.8 had higher education.

Finally, 90.8% were subsistence farmers while 9.2% were involved in local business. Responses from all respondents did not differ significantly between study villages despite of being asked several questions during the interviews.

Abundance of Quelea

The abundance of Quelea was assessed by asking people whether the number of harvested birds was increasing or decreasing. Of all the respondents, 68.6% claimed that the numbers of harvested Quelea were increasing, whereas 31.4% claimed that the numbers of harvested Quelea were decreasing. Among the respon-

dents who claimed that the Quelea populations were increasing (N = 247), 40.6% claimed that it was due to their fecundity, 31.9% claimed that it was due to increased food availability in recent years as a result of increased human population and expansion of cereal crops cultivation and 27.5% claimed that it was due to both breeding efficiency and food availability. Of those who claimed that Quelea populations were decreasing (N = 113), 73.5% claimed the decrease was due to spraying of chemicals. Of these, 49.4% claimed that the decrease was both due to over-harvesting, as well as the spraying of chemicals.

Harvest of Quelea

The majority of respondents (97.5%, N = 360) reported that the red-billed Quelea were harvested in their areas. Most people claimed that the majority of the harvesting occurred during the wet season (73.5%, N = 351), whereas a minority claimed that the harvesting occurred during the dry season (26.5%, N = 351). Among the tools used for harvesting, woven traps (63.2%, N = 351) were mostly used than fishing nets (36.8%, N = 351).

Utilisation of the harvested birds

Almost all (95.6%, N = 360) of the respondents claimed that harvested birds were both consumed and sold. For the birds that were sold, 87.5% (N = 348) claimed that both the streets and bus stops represented the common market places. When sold, 60.8% (N = 348) claimed that the birds were sold as snacks (fried) or fresh meat.

Positive attitudes

The red-billed Queleas were mostly accepted by inhabitants because of their benefits to humans. Seventy-eight percent (N = 282) of those who valued Quelea as food expressed a like for them, whereas 30.8% (N = 78) of those who did not value Quelea as food expressed a similar like (χ^2 = 62.4, df = 1, P < 0.001). Most of the respondents (76.6%, N = 282) who valued Quelea as food agreed that it is a beautiful bird that deserves to live in nature like other living creatures, whereas 39.7% (N = 78) of those who did not value Quelea as food agreed with this statement (χ^2 = 38.5, df = 1, P < 0.001).

The majority (86.7%, N = 256) of respondents who agreed that Quelea have some economic benefits liked them, whereas only 21% (N = 104) of those who did not see any economic benefits of Quelea birds liked them (χ^2 = 145.6, df = 1, P < 0.001). Furthermore, 85.9% (N = 256) of the respondents who claimed that the red-billed Quelea has economic benefits agreed that it is a beautiful bird that deserve to live in nature like other living creatures, whereas only 26% (N = 104) of those who claimed that Quelea has no economic benefits agreed with this notion (χ^2 = 123.5, df = 1, P < 0.001).

Negative attitudes

The majority of respondents (97.5%, N = 360) regarded the Quelea as pests and (80%, N = 360) reported that Quelea birds were the biggest pest problem in the area. Almost all respondents (97.5%, N = 360) claimed that crop damage affected their livelihoods. Furthermore, 96.9% (N = 360) claimed to have experienced crop depredation, of which 71.1% attributed their crop losses to Quelea birds. Among the 96.9% who claimed to have experienced crop depredation, 97.7% (N = 343) regarded the Quelea's as pests (χ^2 = 28.6, df= 1, P < 0.001). However, among the respondents who regarded the Quelea's as pests (97.5%, N = 360), no significant difference was realized between those who agreed (50.7%, N = 360) that Quelea should be exterminated from nature and those who disagreed (49.3%, N = 360) (χ^2 = 0.082, df = 1, P = 0.774).

Strategies used to prevent crop depredation

Scaring (48.1%, N = 360) was the most used method by local people to prevent crop depredation from Quelea birds, followed by spraying of chemicals (31.4%) and harvesting (20.6%). The spraying of chemicals (60.6%, N = 360) was claimed to be the most effective strategy for controlling the Quelea pest problem, followed by scaring (21.7%) and harvesting (17.8%).

Influence of socio-economic factors to human attitudes

The most important socio-economic factors influencing positive attitudes of the respondents were gender and education (Table 1). Men exhibited more positive attitudes than women (Table 1).

The level of education significantly influenced the attitudes of the respondents because most of the respondents with primary education (66.3%, N = 252) agreed that they liked red-billed Quelea because of their benefits. Fewer respondents with no formal education (61.3%, N = 62) or with higher education (47.8%, N = 46) agreed (Table 1). There was no difference in the interactions between sex and education (Wald = 9.29, df = 5, P = 0.098, Table 1). However, there was an interaction between sex and education for both positive questions (Wald = 8.5, df = 5, P = 0.004 and Wald = 8.32, df = 5, P = 0.004, respectively, Table 1). In contrast, the overall statistics of a binary logistic regression analysis was significant only for the question presented in Table 1

Table 1. Positive attitudes of people in relation to socio-economic characteristics as a response to the questions, "Do you like Quelea birds?", "Do you like Quelea because of its benefits?", "Do you agree that the red-billed Quelea is a beautiful bird that deserves to live in nature like other living creatures?" as well as the results of a binary logistic regression analysis with the categorical variables and the interaction between sex*education as independent variable (N = 360).

Category	Indicator	Percentage agreed question 1	Percentage agreed question 2	Percentage agreed question 3	Binary logistic regression analysis					
					Wald 1	P	Wald 2	P	Wald 3	P
Sex	Males	74.1	68.9	74.6	7.6	0.006	6.13	0.01	6.955	0.008
	Females	60.5	56.3	61.7						
Age	18-36 years	70.1	64.2	68.7	0.001	0.991	0.04	0.84	0.009	0.924
	37-54 years	63.4	60.0	69.0						
	>55 years	71.6	66.7	67.9						
Education level	Illiterate	69.4	61.3	64.5	1.13	0.287	1.4	0.24	0.685	0.408
	Primary school	69.0	66.3	69.0						
	Higher education	58.7	47.8	71.7						
Economic activity	Subsistence farming	68.8	63.6	68.5	1.73	0.188	0.46	0.49	0.02	0.888
	Local business	57.6	57.6	69.7						

(Wald = 11.57, df = 5, P = 0.041). The remaining demographic variables of age and economic activity had no significant influence on positive attitudes (Table 1).

Negative attitudes in relation to socio-economic factors

Gender, education and economic activity influenced negative attitudes, whereas age did not (Table 2). Most of the respondents (98.8%, N = 252) with primary education regarded Queleas as pests (Table 2), and in response to another question, 81.3% (N = 252) of these respondents agreed that it is the biggest pest problem in the area (Table 2). Based on the main economic activities, inhabitants whose major economic activity was farming (98.5%, N = 327) regarded the Quelea as pests (Table 2), and in another question, 81.7% (N = 327) of these people agreed that it is the biggest pest problem in the area (Table 2).

Gender elicited an influence on the negative attitudes because a higher percentage of women (59.9%, N = 167) were observed to exhibit more negative attitudes than men (43.0%, N = 193), by accepting the notion that Quelea should be exterminated from nature (Table 2). A binary logistic regression analysis using the three questions in Table 2 as dependent variables and the four demographic variables, as well as the interactions between sex and education as independent variables were significant for each question (Tables 2). In contrast, the interaction between sex and education was significant only for the question "Do you agree that Quelea is the biggest pest problem?"(Wald = 5.91, df = 5, P = 0.041).

DISCUSSION

Demographic characteristics of respondents

The general characteristics of the respondents listed in Table 1 reflect their influence on human attitudes toward the red-billed Quelea. The education level is normally one of the important factors that influences human attitudes (Røskaft, 2012; Røskaft et al., 2003; Røskaft et al., 2007). However, in this study, most of the respondents had primary education because it is compulsory and less expensive to attain compared to higher education. The majority of the respondents were subsistence farmers.

General management of the red-billed Quelea

As a way to protect cereal crops using chemical measures, both direct and indirect hazards can occur from the spray application and consumption of contaminated food (Cheke et al., 2012). For instance, in Kondoa, Quelea birds are used as food, and sometimes, the local inhabitants collect contaminated birds for consumption immediately after chemical spraying (Masare, pers. comm. 2012). This has happened even in other parts of Africa, including Chad and Cameroon, where the local inhabitants use Quelea birds as food (Mullie, 2000).

Table 2. Negative attitudes of people in relation to socio-economic characteristics as a response to the questions, "Do you regard Quelea as a pest?", "Do you agree that Quelea is the biggest pest problem?", "Doyou agree that Quelea is a pest that should be exterminated from nature?" as well as results of a binary logistic regression analysis with the categorical variables and the interaction between education*sex as independent variables (N = 360).

Category	Indicator	Percentage agreed question 1	Percentage agreed question 2	Percentage agreed question 3	Binary logistic regression analysis					
					Wald 1	P	Wald 2	P	Wald 3	P
Sex	Males	97.4	81.3	43.0	0.014	0.906	0.472	0.49	10.20	0.001
	Females	97.6	78.4	59.9						
Age	18-36 years	96.3	75.4	48.5	0.556	0.456	3.263	0.07	0.001	0.994
	37-54 years	98.6	81.4	55.2	0.001	0.991				
	>55 years	97.5	85.2	46.9						
Education level	Illiterate	96.8	85.5	46.8	2.203	0.138	6.061	0.01	0.001	0.979
	Primary school	98.8	81.3	52.8						
	Higher education	91.3	65.2	45.7	1.13	0.287	6.08	0.01	1.03	0.311
	Subsistence farming	98.5	81.7	51.7	13.8	0.001				
	Local business	87.9	63.6	42.4						
Economic activity	Males	97.4	81.3	43.0	0.014	0.906	0.472	0.49	10.20	0.001
	Females	97.6	78.4	59.9	1.73	0.188				
	18-36 years	96.3	75.4	48.5	0.556	0.456	3.263	0.07	0.001	0.994

Similar secondary effects can occur by biomagnification via other organisms, such as when carnivorous mammals, birds and reptiles consume contaminated Quelea birds. Moreover, the efficiency of chemical control remains questionable since it is difficult to monitor the number of killed birds at any time in all treated places to ensure that the population size remains viable for future generations. Therefore, a new practical, economical and high efficiency control measure for the Quelea birds that does not adversely damage the ecosystem or impact the non-targeted species and the environment is needed in the future.

Abundance of Quelea

Generally, the red-billed Queleas are regarded as the most abundant wild birds in the world and as a IUCN least concern status (IUCN, 2012). In this study the abundance was assessed by asking the inhabitants whether the number of harvested birds were increasing or decreasing, despite the increased demand attributed to the growth of the human population. The majority of the respondents claimed that the numbers of harvested Quelea were increasing, although a few respondents claimed that the numbers were decreasing. All these respondents claimed that the decline was mainly due to spraying of chemicals followed by over-harvesting. The spraying of chemicals was claimed to kill large numbers of Quelea because of the toxic chemicals used. In contrast, over-harvesting was considered as the least concern due to insignificant numbers of killed birds through harvesting compared to the spraying of toxic chemicals but harvesting can turn to be more destructive if all households in the district will engage in catching and consuming the birds beyond sustainable level. Most respondents perceived the Quelea populations as significantly abundant because their numbers have been increasing particularly during the wet season. High fecundity, followed by increased food availability, was claimed as the major reason for the enormous Quelea populations in Kondoa. Similar reasons have also been reported by others under ecological studies for Quelea abundance (Cheke, 2003; Cheke et al., 2007; Dallimer and Jones, 2002; Elliott, 2006; Venn et al., 2003).

Harvest of Quelea

Most of the respondents reported that the Quelea birds were harvested in their areas during both seasons of the year but mostly during the dry season (July to October). In Kondoa, enormous Quelea populations occur during the wet season following the breeding season. The Quelea use this time to breed because of the high abundance of growing cereal crops that can provide adequate amount of food for their juveniles (Allan, 1996). The juveniles are the most destructive birds compared to adults because they lack experience in searching for their preferred natural foods (Cheke et al., 2012; Hartley and

Mundy, 1999; Jones et al., 2002). People claimed to harvest large numbers of Quelea birds, particularly juveniles during that period. Among the tools used for harvesting, woven traps were claimed to be used more often than fishing nets because fishing nets were banned in Tanzania as a strategy to prevent the fishing of young fishes.

Utilisation of the harvested birds

Harvested Quelea birds were mostly used as food within households whereas some were sold to passengers at bus stops or to other households within the area. According to the nature of the area, there were few other sources of protein food, including meat and it is expensive to produce meat in the semi-arid area of Kondoa, where shortages of water and green pastures are common during dry season.

Positive attitudes

The red-billed Quelea was perceived as good and accepted by local people because of its values to humans. This supports our hypothesis that positive attitudes of people towards the red-billed Quelea are influenced by the Quelea benefits. The majority who valued Quelea as food liked it and accepted existence of Quelea in their areas as one of the food sources for their households. Very few people exhibited positive attitudes that were not associated with benefits. The opportunity of using Quelea birds as food created positive attitudes in people because most of them had experienced this type of benefit despite the costs caused by Quelea pests. The Quelea benefits were also recognised economically by people who trapped Quelea birds for selling.

Negative attitudes

The majority of respondents consider the Queleas as pests and claim to have experienced crop damage that has resulted predominantly from Quelea birds. Crop damage is among the major constraints facing crop production in Kondoa, along with drought, lack of agricultural inputs, poor soils, diseases and other pests. Almost all respondents claimed that crop damage affects their livelihoods. It increases the problem of food insecurity, which is common in semi-arid areas of Tanzania, as well as other parts of Africa (Mfunda and Røskaft, 2011).

Approximately half of respondents agreed that Quelea should be exterminated from nature because of their role as a major pest of small grain cereal crops in the area. Some inhabitants were ambivalent, but those who were engaged in the business of selling harvested Quelea birds exhibited more positive attitudes than those who did not particularly farmers. This observation supports the second hypothesis that negative attitudes are highly influenced by Quelea-related costs.

Strategies used to prevent crop depredation

All of the control measures for Quelea are categorised into the following two main types; scientific and traditional measures. The effectiveness of all of the management techniques depends on many factors including pest species and their biology, pest population size, farm size and ownership, value of crop being damaged, type and stage of the crop, time of the year or season, resources available for control operation and human attitudes toward the chosen control method (Allan, 1996; Ezealor and Giles, 1997; Ruelle and Bruggers 1982). Inspite of being tedious and time-consuming, bird scaring was predominantly used by local inhabitants of Kondoa to protect crops against Quelea birds and other pests. Scaring the birds away has been practiced in various traditional forms using noise-making objects such as plastic, papers and cloth flags attached to a line of cords tied to poles. Scaring birds away can also be accomplished using guards or scarers that roam around the field, whipping, clapping, shouting and throwing stones. Scaring methods have been employed by traditional farmers in different parts of Africa over centuries as the first option for small scale farmers (Allan, 1996; Ruelle and Bruggers, 1982). Despite all the facts, the scaring strategy was observed to have little impact on the alleviation of Quelea pest problem (Allan, 1996; Garanito et al., 2000).

Spraying of chemicals has been claimed to represent a more effective strategy for controlling the Quelea pest problem than bird scaring or harvesting. The people of Kondoa have perceived it as the most effective method simply because it kills larger numbers of Queleas within a shorter period of operational time. The fact that the people of Kondoa did not incur any chemical control economical cost was another reason for their perception; it was the best control measure, in addition to the possibility of collecting the nearly dead birds for their own consumption. Furthermore, the majority of local inhabitants know less about the harmful effects of such chemicals that can pollute the environment and damage the ecosystem.

The harvesting method has also been used by some people in Kondoa to control Quelea pest problem. It was also performed as a way to amass Quelea birds as food for households, as well as a business for generating income through selling of the harvested birds. Traditionally, Quelea birds have been used as food sources by rural communities in some African countries, including Tanzania, for many years (Mullie, 2000). Harvesting birds that are considered as pests also represents a way of compensating subsistence farmers

for the lost yields by using those birds as food or as a source of cash income (Allan, 1996). Despite being used by the inhabitants of Kondoa for many years, the harvesting strategy has also failed to resolve the problem of crop damage because the traps used are locally constructed and small in size. Such traps can only catch a maximum of 30 to 50 birds per trap. A better option in terms of sustainable harvesting if well coordinated is to slightly modify the traps.

Influence of socio-economic factors to human attitudes

Factors such as level of education, gender and economic activities have also been reported to influence human attitudes toward wildlife (Kideghesho et al., 2007; Naughton-Treves et al., 2003; Røskaft et al., 2007). The most important socio-economic factors observed to influence both positive and negative attitudes were gender and education,while economic activities only influenced the negative attitudes. The men, who were more involved in the Quelea business, received more benefits than women, who were less involved. Most inhabitants with primary education and whose major economic activity was farming considered the red-billed Queleas as pests and the biggest pest problem in their areas.

Conclusion

Both positive and negative attitudes were expressed by the inhabitants of Kondoa and were influenced by the costs and benefits of the Quelea birds, as well as by socio-economic factors (gender, education level and economic activity). Crop damage induced by Quelea birds was the predominant cause of negative attitudes despite the benefits obtained from the harvested Quelea birds. To change such negative attitudes, practical, economical, and applicable solutions for the Quelea pest problem are needed. The harvesting of Quelea birds can help to reduce the level of crop damage. Sustainable harvesting is highly recommended because it does not significantly impact Quelea populations compared to environmental factors such as drought, which can rapidly reduce their reproductive and survival fitness (Mullie, 2000).

REFERENCES

Allan RG (1996). The grain-eating birds of Sub-Saharan Africa: Identification, biology and management. Chatham, UK, Natural Resources Institute.

Cheke RA (2003). Forecasting movements and breeding of red billed Quelea bird in Southern Africa and improved control strategies. University of Greenwich, Natural Resources institute.

Cheke RA, McWilliam AN, Mbereki C, van der Walt E, Mtobesya B, Magoma RN, Young S, Eberly JP (2012). Effects of the organophosphate fenthion for control of the red-billed Quelea *Quelea quelea* on cholinesterase and haemoglobin concentrations in the blood of target and non-target birds. Ecotoxicology 21(7):1761-1770.

Cheke RA, Venn JF, Jones PJ (2007). Forecasting suitable breeding conditions for the red-billed quelea *Quelea quelea* in Southern Africa. J. Appl. Ecol. 44(3):523-533.

Dallimer M, Jones PJ (2002). Migration orientation behaviour of the red-billed quelea *Quelea quelea*. J. Avian Biol. 33(1):89-94.

Dar NI, Minhas RA, Zaman Q, Linkie M (2009). Predicting the patterns, perceptions and causes of human-carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. 142(10):2076-2082.

de Mey Y, Demont M, Diagne M (2012). Estimating bird damage to rice in Africa: Evidence from the Senegal River Valley. J. Agric. Econ. 63(1):175-200.

Elliott C, Bright E (2007). Review of the bird pest problem and bird scaring in South west Nigeria. PrOpCom Monographs. Abidjan, Nigeria, Department of International Development: p. 35.

Elliott CCH (1979). Harvest time method as a means of avoiding quelea damage to irrigated rice in Chad Cameroon. J. Appl. Ecol. 16(1):23-35.

Elliott CCH (1990). The migrations of the red-billed quelea *Quelea quelea* and their relation to crop damage. Ibis 132(2):232-237.

Elliott CCH (2006). Bird population explosions in agroecosystems - the quelea *Quelea quelea,* case history. Acta Zool. Sin. 52:554-560.

Ezealor AU, Giles RHJ (1997). Vertebrate pests of a Sahelian wetland agroecosystem: Perceptions and attitudes of the indigenes and potential management strategies. Int. J. Pest Manage. 43(2): 97-104.

Garanito M, Botha MJ, van der Westhuizen L (2000). Alternative strategies for red-billed quelea population management. Workshop on research priorities for migrant pests of agriculture in Southern Africa. Cheke RA, Rosenberg LJ, Kieser ME. Chatham, UK, Natural Resources Institute. pp. 119-123.

Gereta EJ, Røskaft E, Eds (2010). Conservation of natural resources: Some African and Asian Examples. Trondheim, Norway, Tapir academic press.

Gillingham S, Lee PC (1999). The impact of wildlife-related benefits on the conservation attitudes of local people around the Selous Game Reserve, Tanzania. Environ. Conserv. 26(3):218-228.

Hanley N, Czajkowski M, Hanley-Nickolls R, Redpath S (2010). Economic values of species management options in human-wildlife conflicts Hen Harriers in Scotland. Ecol. Econ. 70(1):107-113.

Hartley RR, Mundy P (1999). Sustainable development and natural resources management in Southern Zimbabwe. Birds surveys. Affairs IMoF. Harare, Bulawayo, Biodiversity Foundation for Africa- BFA: p. 87.

Hemson G, Maclennan S, Mills G, Johnson P, Macdonald D (2009). Community, lions, livestock and money: A spatial and social analysis of attitudes to wildlife and the conservation value of tourism in a human-carnivore conflict in Botswana. Biol. Conserv. 142:2718-2725.

Holmern T, Nyahongo JW, Røskaft E (2007). Livestock loss caused by predators outside the Serengeti National Park, Tanzania. Biol. Conserv. 135(4):534-542.

Ikanda D (2010). Large carnivore attacks on people and the human-carnivore conflict. Conservation of natural resources; Some African & Asian examples. Gereta E, Røskaft E. Trondheim, Tapir academic press: pp. 270-287.

Ikanda D, Packer C (2008). Ritual vs. retaliatory killing of African lions in the Ngorongoro Conservation Area, Tanzania. Endang. Species Res. 6: 67-74.

IUCN (2012). The IUCN red list of threatened species. Retrieved 10.12.2013, from www.iucnredlist.org.

Jones PJ, Elliott CCH, Cheke RA (2002). Methods for ageing juvenile red-billed queleas, *Quelea quelea*, and their potential for the detection of juvenile dispersal patterns. Ostrich 73(1-2):43-48.

Kaltenborn BP, Bjerke T, Nyahongo JW (2006). Living with problem animals - self-reported fear of potentially dangerous species in the Serengeti Region, Tanzania. Human Dimens. Wildl. 11(6):397-409.

Kideghesho JR, Røskaft E, Kaltenborn BP (2007). Factors influencing conservation attitudes of local people in Western Serengeti, Tanzania. Biodivers. Conserv. 16(7): 2213-2230.

Løe J, Røskaft E (2004). Large carnivores and human safety: A review. Ambio 33(6): 283-288.

Markula A, Hannan-Jones M, Csurhes S (2009). Pest animal risk assessment: red-billed quelea. (*Quelea quelea*). Invasive Plants and Animals. Biosecurity Queensland, Queensland Primary Industries and Fisheries.

Mfunda IM, Røskaft E (2011). Wildlife or crop production: the dilemma of conservation and human livelihoods in Serengeti, Tanzania. Int. J. Biodivers. Sci. Ecosyst. Serv. Manage. 7(1):39-49.

Mullie WC (2000). Traditional capture of red-billed Quelea *Quelea quelea* in the Lake Chad Basin and its possible role in reducing damage levels in cereals. Ostrich 71(1-2):15-20.

Naughton-Treves L, Grossberg R, Treves A (2003). Paying for tolerance: Rural citizens' attitudes toward wolf depredation and compensation. Conserv. Biol. 17(6):1500-1511

Nyahongo JW (2010). Depredation of livestock by wild carnivores and illegal utilisation of natural resources by humans in western Serengeti, Tanzania. Conservation of natural resources; Some African and Asian examples. Gereta E, Røskaft E. Trondheim, Tapir academic press. pp. 255-269.

Packer C, Ikanda D, Kissui B, Kushnir H (2005). Lion attacks on humans in Tanzania - Understanding the timing and distribution of attacks on rural communities will help to prevent them. Nature 436(7053):927-928.

Røskaft E (2012). Human-wildlife Interactions in Africa and Asia: A special reference to Tanzania and Bangladesh. Proceedings of the International Conference on Biodiversity - Present State, Problems and Prospects of its Conservation. Røskaft E, Chivers DJ. Trondheim, NTNU trykk. pp.14-21.

Røskaft E, Bjerke T, Kaltenborn BP, Linnell JDC, Andersen R (2003). Patterns of self-reported fear towards large carnivores among the Norwegian public. Evol. Hum. Behav. 24(3):184-198.

Røskaft E, Händel B, Bjerke T, Kaltenborn BP (2007). Human attitudes towards large carnivores in Norway. Wildl. Biol. 13(2):172-185.

Ruelle P, Bruggers RL (1982). Traditional approaches for protecting cereal crops from birds in Africa. Vertebrate Pest Conference Proceedings collection, University of Nebraska, Lincoln.

Treves A, Wallace RB, Naughton Treves L, Morales A (2006). Co-managing human-wildlife conflicts: A review. Hum. Dimens. Wildl. 11:1-14.

Treves A, Karanth KU (2003). Human-carnivore conflict and perspectives on Carnivore management worldwide. Conserv. Biol. 17(6):1491-1499.

URT (2013a). Dodoma Region Profile. http://www.tanzania.go.tz, Tanzania National website.

URT (2013b). Population and housing census counts 2012. http://www.nbs.go.tz, Tanzania, National Bureau of Statistics.

Venn JF, Cheke RA, Jones PJ (2003). Forecasting breeding opportunities for the red-billed Quelea in Southern Africa. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.2.9406, CiteSeer.

academicJournals

Vol. 6(2), pp. 148-158, February 2014
DOI: 10.5897/IJBC2013.0564
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

A multi-method approach for the inventory of the adult population of a critically endangered crocodilian, the Gharial (*Gavialis gangeticus*) at Dhikala, Corbett Tiger Reserve incorporating direct counts and trail cameras

S. M. Chowfin[1]* and A. J. Leslie[2]

[1]The Gadoli and Manda Khal Wildlife Conservation Trust, P.O. Box 27, Pauri, District Pauri Garhwal, Uttarakhand, India.
[2]Department of Conservation Ecology and Entomology, Faculty of Agri Sciences, University of Stellenbosch, Matieland, 7600, South Africa.

Accepted 12 December, 2013

The Corbett Tiger Reserve (CTR), a very highly rated protected area in the State of Uttarakhand, India, is home to the third largest breeding population of adult gharial globally. It contributes 20% to the estimated global population of 200 - 250 adults of the taxon and it is also the only known population of the taxon which lives predominantly in a lake-like environment. CTR was surveyed for gharial in 2008 which was the first systematic survey with regard to the taxon since 1974 and the meta-population here was found distributed amongst six sub-populations in the Sarpduli, Dhikala, Kalagarh, Sonanadi, Palain and Adnala Ranges of the Reserve. This paper documents a multi-method approach for the estimation of gharial at Dhikala (Dhikala Range) namely: at the confluence of the Ramganga River with the Kalagarh Reservoir. It details the use of trail cameras combined with boat surveys along the shoreline and stationary counts for estimating the adult population of gharial at Dhikala, the site of the largest sub-population of gharial in CTR. Using this multi-method approach to count basking animals, we estimated the adult population in the area to consist of 32 adults (inclusive of seven adult males) based on the maximum ± minimum (MM) method. We also considered the unknown proportion of adults that may have gone undetected during these surveys by subjecting the data to a Double Sampling analysis. The results are indicative that we were able to sample 88.9% of the adult gharial population at Dhikala using this Multi-Method Approach. Based on our three population estimates (n= 29, 32 and 36) we averaged the adult population at Dhikala as 32.3 ± 1.69 adults (Mean ± SE) with an encounter rate of 4.01 ± 0.33 adults km^{-1} over 8.06 km of shoreline. Further, comparing population estimates between 2008 and 2013 based on the maximum ± minimum (MM) method, we estimated that the number of adults in Dhikala increased by 77.8% between 2008 and 2013. This increase in adult gharial numbers detected in the study area between 2008 and 2013 is primarily a result of: (1) Improved survey techniques which detected more number of animals in the area due to the cumulative effects of population growth from sub-adults to adults, in-migration and the possibility of some animals being missed during the 2008 surveys; (2) improved knowledge and familiarity with the study area; (3) effective protection measures already in place in CTR particularly in Corbett National Park (CNP), which has allowed the adult population to increase naturally without any disturbances. The ability of this multi-method approach in detecting these changes in numbers is important for monitoring the taxon and studying population trends within CNP.

Key words: Gharial, *Gavialis gangeticus*, Corbett Tiger Reserve, Corbett National Park (CNP), trail cameras.

INTRODUCTION

The gharial (*Gavialis gangeticus*), which is a freshwater crocodile endemic to the North Indian Sub-Continent, was categorized as Endangered up until its up listing to Critically Endangered in 2007. The population at present is estimated at no more than 200 - 250 adults globally (Choudhury et al., 2007 in IUCN, 2013).

The factors identified for the decline of the gharial population in the past 60 years have been over hunting for skin and trophies, egg collection for consumption, killing for indigenous medicine, and retaliatory killing by fishermen. Dams, barrages, irrigation canals, siltation, changes in river courses, artificial embankments, sand mining, riparian agriculture and land use changes to accommodate domestic and feral livestock have all caused irreversible loss of riverine habitat contributing to limiting the range of the taxon. These threats continue to increase further threatening the very survival of the species (Whitaker et al., 2007).

Until 2008, Corbett Tiger Reserve (CTR) was home to very few gharial, with limited breeding success and therefore with a negligible contribution towards the global gharial population. Due to these factors, the gharial population in CTR has never been surveyed systematically and thus remains one of the least studied and therefore least understood of the global gharial populations. The Reserve was systematically surveyed for Gharial in the winter month of February, 2008, which was the first systematic survey conducted on the taxon since 1974 (Whitaker, 1979), by counting basking animals and the meta-population in CTR was estimated to consist of 42 adults, inclusive of 10 adult males and 59 smaller size classes distributed amongst six sub-populations. These were the Ramganga River (Sarpduli and Dhikala Ranges), Dhikala (Dhikala Range), Gaujeda (Adnala Range), Palain River (Palain and Adnala Ranges), Sonanadi River (Sonanadi Range) and Boksar (Kalagarh Range) sub-populations. These surveys confirmed that CTR is home to the third largest population of the taxon globally and contributes 20% towards the 200 - 250 estimated global adult population. The Gharial meta-population in CTR may best be described as an endemic as it is a closed population. It is also the only known population of the taxon which lives and breeds predominantly in a lake-like environment (The Wildlife Chronicles www.subirchowfin.blogspot.com).

Two hundred and fifty seven (257) captive breed gharial were also released in CTR and these releases were limited only to a 40 km stretch of the Ramganga River. It was estimated from these releases that only eight individuals survived to adulthood (Rao et al., 1995). Available data indicate that these releases were conducted in eight batches between 1985 and 1994 (pers.comm. Basu, 2008) (Table 1). However, data on the size classes of the animals released was unavailable.

Table 1. Gharial release, CNP (pers.comm. Basu, 2008).

Date of release	Numbers released
24 March, 1985	16
24 March, 1985	11
12 April, 1990	40
27 March, 1991	25
20 November, 1991	55
4 February, 1993	35
6 March, 1994	25
12 March, 1994	50
Total	257

With no further releases for the next 20 years, corresponding to a generation length of the taxon since the last releases in 1994, the Corbett meta-population sustained itself during this period and indicates that some of the gharial sub-populations in CTR, like those found in Boksar, Palain and Sonanadi, may have lived and breed largely undetected, being a part of the original gharial meta-population in CTR which remained unknown until the surveys conducted in 2008.

Surveys in 2008 and since suggest that the recruitment of gharial in CTR is primarily through natural regeneration as is evidenced by the current population structure of gharial in Corbett National Park (10 adult Males, 39 adults, 16 sub-adults, 4 juveniles, 2 yearlings and 350-400 hatchlings recorded in surveys this far and which are in progress) as well as the presence of nesting areas (Chowfin, 2010, 2011; Chowfin and Leslie; 2013).

MATERIALS AND METHODS

Study area

The core area of CTR, formerly known as Hailey National Park, was the first such Park to be created in India in 1936. It was renamed Corbett National Park in 1956-1957 and declared a Tiger Reserve in 1991. The reserve is situated at the foothills of the Western Himalayas in the civil districts of Nainital, Almora and Pauri Garhwal in Uttarakhand and encompasses an area of 1288.3 km². This is comprised of 520.8 km² of Corbett National Park, 301.1 km² of Sonanadi Wildlife Sanctuary and the remaining 466.3 km² are buffer areas. The reserve lies between Latitude 29°25′N to 29°40′N and Longitude 78°5′E to 79°5′E. Geologically, the park belongs to Shivalik formations composed of conglomerates, sand, rocks, stones and boulders. The altitude varies from 330-1200 m with undulating topography. The building of the Kalagarh Dam in 1974 on the Ramganga River led to the formation of the Kalagarh Reservoir (84 km²) altering riverine habitat in CTR along the Ramganga River to a predominantly lake-like habitat. The aquatic habitat in CTR consists of the Mandal, Palain and Sonanadi rivers which are tributaries of the Ramganga River within the Reserve, the 84 km² Kalagarh Reservoir and numerous mountain springs called *sots*. The IUCN WCPA recognizes Corbett National Park as a

*Corresponding author. E-mail: schowfin@yahoo.com. Tel: + 91-8126915911.

Table 2. Gharial size classes, 2011 - 2012.

Adult male with Ghara	Adult w/o Ghara	Large adult	Medium sized adult	Small adult	Large Sub adult	Small Sub adult	Large juveniles	Small Juveniles	Yearlings	Hatchlings
> 4 m	> 4 m	3.6 - 4 m	3 m - 3.6 m	2.7 - 3 m	2.4 - 2.7 m	2.1 - 2.4 m	1.8 - 2.1 m	0.9 - 1.8 m	0.6 - 0.9 m	0.3 - 0.6 m
>400 cm	>400 cm	360 - 400 cm	300 - 360 cm	270 - 300 cm	240 - 270 cm	210 - 240 cm	180 - 210 cm	90 - 180 cm	60 - 90 cm	30 - 60 cm

Table 3. Gharial size classes, 2013.

Adult Male with Ghara	Adult w/o Ghara	Adult	Sub Adult	Juvenile	Yearling	Hatchling
> 4 m	> 4 m	2.7 - 4 m	2.1 - 2.7 m	0.9 - 2.1 m	0.6 - 0.9 m	0.3 - 0.6 m
>400 cm	>400 cm	270 - 400 cm	210 - 270 cm	90 - 210 cm	60 - 90 cm	30 - 60 cm

Category II Protected Area and the Sonanadi Wildlife Sanctuary as a Category IV Protected Area.

The study area in Corbett Tiger Reserve is limited to the following Ranges: 1) Sarpduli (Corbett National Park); 2) Dhikala(Corbett National Park); 3) Kalagarh (Corbett National Park); 4) Sonanadi (Sonanadi Wildlife Sanctuary); 5) Palain (Sonanadi Wildlife Sanctuary); 6) Adnala (Sonanadi Wildlife Sanctuary).

Use of Trail cameras to monitor wildlife populations

Trail Cameras are a powerful tool in the management of wild animal populations and data can be collected on presence/absence, animal movement and range size, minimum population size, demographic data (for example buck:doe and fawn:doe ratios), identifying nest predators, or cataloging vertebrate diversity.

Trail cameras have been extensively used in estimating densities of tigers, bobcats, snow leopards, jaguars, leopards etc by Capture - Recapture methods which are possible by studying pelage patterns in the identification of individuals (Larrucea et al., 2007) while Tobler et al. (2008) demonstrated the effectiveness of camera traps for inventorying large- and medium-sized terrestrial animals.

With regard to crocodilian species, trail cameras have proved valuable in monitoring nest predators as demonstrated by a study of *Crocodylus johnstoni* nests in Lake Argyle depredated by dingos (Somaweera et al., 2011).

Methodology

The Dhikala sub-population is found at the Ramganga - Kalagarh Reservoir Confluence in CNP which consists of mud-flats and sand banks with the Ramganga River bifurcating into two before it joins the reservoir. The distribution of mud flats and sand banks undergo seasonal changes depending on monsoonal rains in the Ramganga Catchment of the Central Himalayas of Uttarakhand. Estimating the gharial sub-population in Dhikala is very challenging and thus ideally best conducted by first observing the topography of the mud-flats and sand banks along with the distribution of basking gharial in the area, before starting the actual count.

To estimate the population of adults in the area, we first used the maximum ± minimum (MM) method. Messel et al. (1981 in Seijas et al., 1999) described this method as calculating the population structure of crocodiles using the maximum number of individuals in a particular size category, regardless of the survey in which they were observed. This is then assumed to be the best estimate for that particular size class for that year.

Using a single observer, surveys in 2008 were conducted in February using a 3.6 m fibre-glass boat (fitted with a 25 Hp petrol engine) by moving along the shoreline. Observations of basking gharial were made from the boat using a pair of Nikon 7x binoculars and basking gharial were assigned to pre-determined size classes based on these ocular estimates.

To estimate the population size of gharial in CTR in 2011-2012 a size classification was predetermined (Table 2) with the aim of detecting minor changes in population structure over a multi-year period. However, during field surveys, it was found that such a size classification was ambitious and unworkable in most situations being affected by sighting distances between the observer and animals. This often led to difficulties in size classification. In addition, approaching gharial by boat to reduce sighting distances often resulted in disturbing them, causing the animals to swim back into the water.

To overcome these difficulties, a revised size classification was used in 2013 so as to classify animals from an observable distance without disturbing them during the count (Table 3). This size classification was found workable during field surveys and there was minimized chance of error during data entry in the field when undertaking visual observations.

To estimate the population of adults at Dhikala in 2013, surveys were conducted during February (winter) using a multi-method approach to count basking gharial. This multi-method approach included the use of trail cameras, boat surveys along the shoreline, stationary counts and a

Map 1. Demarcation of Dhikala into three sections for purposes of surveys, CTR.

Single Observer as part of this exercise. Survey routes and field events were recorded on a Garmin 72H GPS unit while photographs for photographic enumeration were taken using a Canon 1000D camera attached to a Celestron Spotting Scope at 20x and 40x magnification. Nikon 10 × 50 Binoculars were used for scanning the area for basking groups and individual basking gharial. While conducting boat surveys along the shoreline we used a 3.8 m inflatable boat fitted with a Torqeedo 1003 s Electric Boat Engine, with low decibels as compared to a petrol engine. Advantages included fewer disturbances to the animals as well as being able to access shallower sections of the shoreline.

The study site at Dhikala was first categorized into three areas / sections as was done in 2008 for the purpose of the count (Map 1). These were: 1) The Dhikala Channel; 2) The Dhikala Channel to Phulai Channel Area; 3) The Phulai Channel.

Systematic surveys of these sections were conducted by repeated boat surveys along the shoreline totaling 32.2 km. The average survey route was 8.06 km in length while shoreline surveys between Dhikala and Gaujeda were 16 km in length. We also conducted stationary counts using 1 h class intervals along with photographs of basking congregations and individual gharial and placed trail cameras in the area. Basking gharial from visual observations during surveys by boat along the shoreline and stationary counts were enumerated on the spot and placed into predetermined size classes as detailed in Table 3. Additionally, basking groups were also photographed for photographic enumeration especially in locations where trail cameras were not placed but where gharial congregated along the shoreline (Figure 2).

Prior to the start of the survey, we observed the area for two days to identify “trap spots” which can best be described as locations used by gharial basking groups along the shoreline. We used this approach for positioning cameras so as to maximize photo captures due to the availability of only a few cameras (n = 3). Once these sites were identified, gharial spoor at these locations were used as a reference for the placement of trail cameras by keeping a minimum of 10-15 m between the spoor and the camera. Three time lapse trail cameras were placed at different locations where basking gharial congregated along the shoreline.

The cameras were placed before the start of the day long basking schedules between 7:00 to 8:00 h and were removed once basking schedules and gharial numbers decreased after 16:00 h. Specific spots for placement of trail cameras at a site varied daily; however, the general locations remained broadly the same (Map 2). A time lapse interval of 10 s was set on each trail camera. Camera images were studied to determine group sizes and cohorts of basking congregations (Figure 1). The trail cameras helped in demarcating the study site into more manageable counting units by performing stationary counts at these so called “Trap Spots”. This had the added advantage of reducing the number of surveys

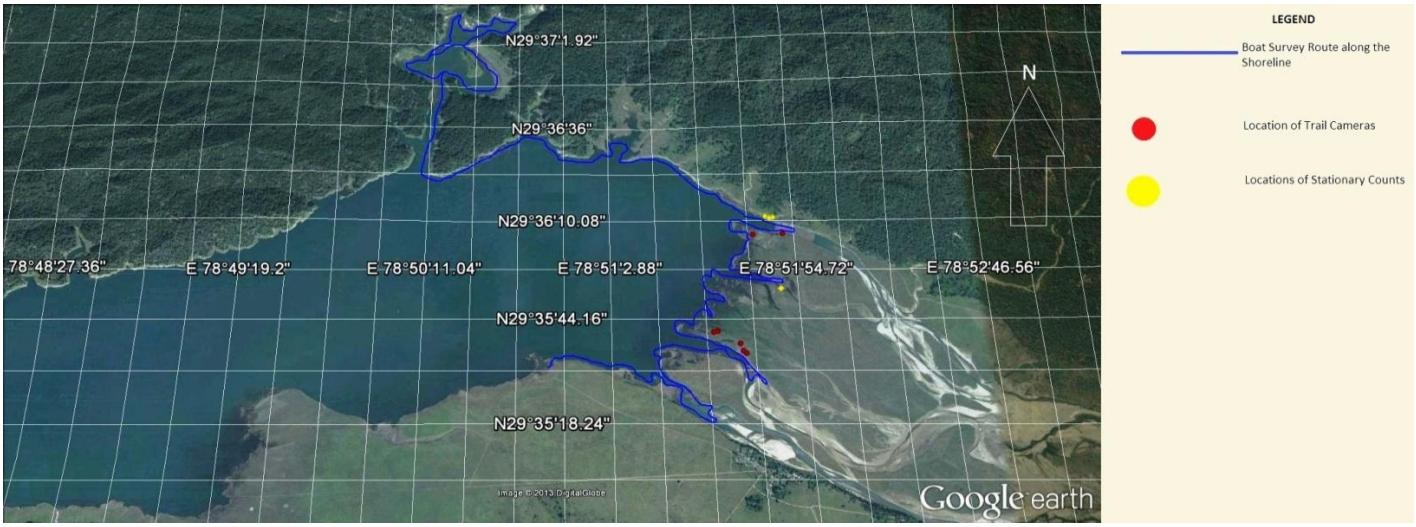
Figure 1. Time Lapse Sequence from a “Trap Spot” of basking Gharial of various size classes, Dhikala, CTR.

conducted by boat thereby reducing disturbances in the study area during surveys and errors that could occur during Direct Counts from Observers (Ogurlu et al., 2013), leading to improved counts at the study site.

Ocular estimates were conducted during boat surveys and whenever possible gharial were also photographed for photo estimates while stationary counts from vantage points were undertaken with counts being conducted every hour. A day’s count at the end of each day’s survey consisting of gharial numbers from boat surveys, stationary counts photo enumeration and trail cameras was tabulated and the population of adults was estimated using the Maximum ± Minimum (MM) method (Table 4, Graph 1).

We also considered estimating the unknown proportion of adults that may have gone undetected during these surveys. For this we subjected our data to a Double Sampling Analysis where we treated the surveys on 21/2, 22/2 and 24/2 as “Intensive Surveys” followed by a

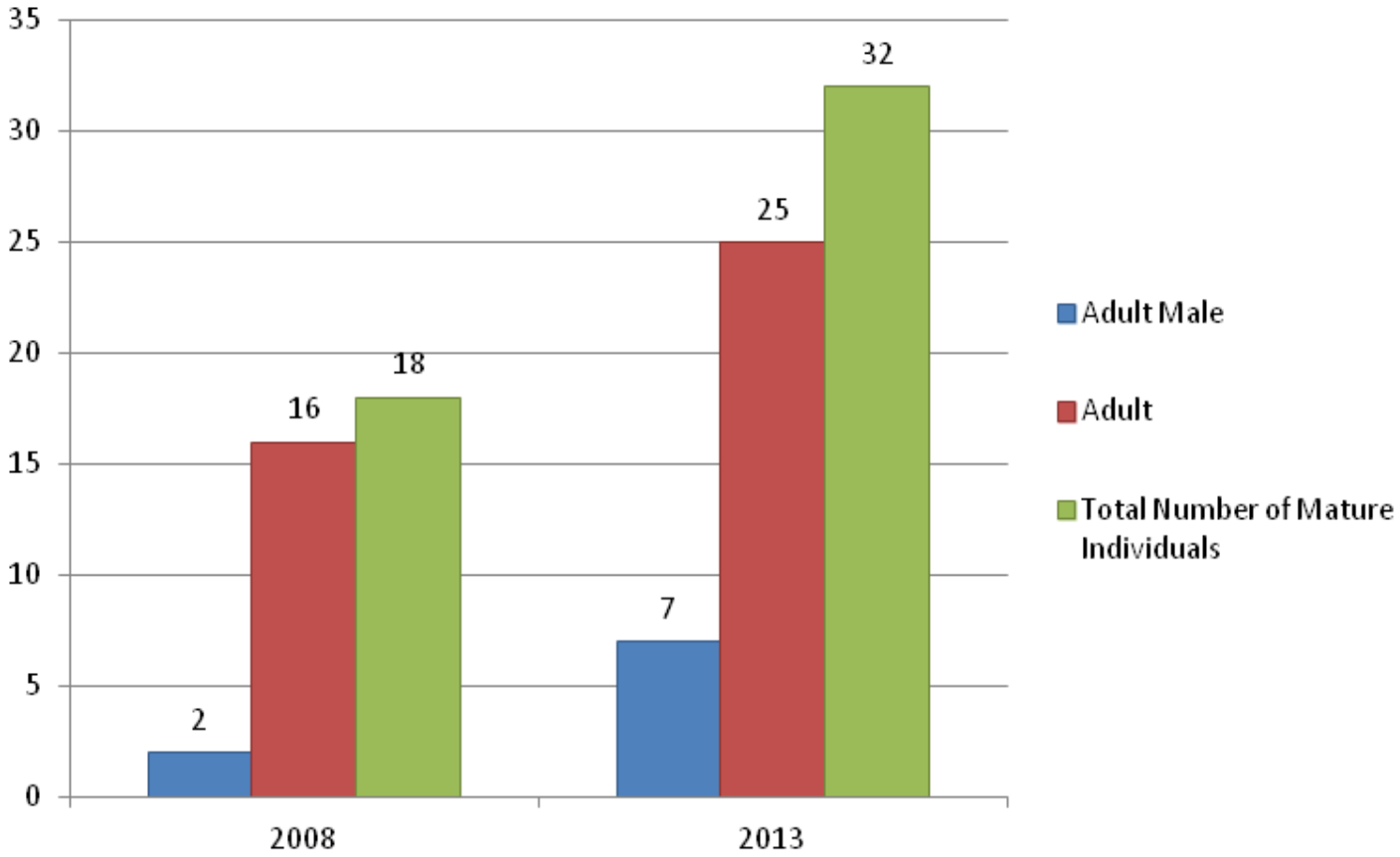
Figure 2. Photo enumeration of a basking gharial congregation in Dhikala, CTR.



Map 2. Boat survey routes, trail camera locations and stationary count locations.

Table 4. Counts of Adult Gharial, Dhikala, 2013.

Date	Type of survey	Adult Male	Adult	Total
	Boat Survey	1	9	10
21/2/2013	Stationary Count	6	14	20
Intensive Survey	Trail Cameras	0	0	0
	Days Count	7	23	30
	Boat Survey	4	4	8
22/2/2013	Stationary Count	2	14	16
Intensive Survey	Trail Cameras	0	7	7
	Days Count	6	25	31
23/2/2013	Survey abandoned due to bad weather			
	Boat Survey	6	14	20
24/2/2013	Stationary Count	0	3	3
Intensive Survey	Trail Cameras	1	2	3
	Days Count	7	19	26
25/2/2013	Boat Survey	7	20	27
Rapid Survey	Days Count	7	20	27
	Population Estimate using Double Sampling Analysis (Intensive Surveys)	7	22	29
	Population Estimate using the Maximum - Minimum Method	7	25	32
	Population Estimate based on the relation N=c/p	7	29	36
	Mean Population Estimate	7	25.33	32.33



Graph 1. Estimates of Adults in 2008 and 2013 using the Maximum ± Minimum (MM) Method, Dhikala, CTR.

"Rapid Survey" by boat along the Dhikala shoreline.

RESULTS AND DISCUSSION

Trail Cameras have been used in the monitoring of West African Nile Crocodile and West African Dwarf Crocodile at the Simandou Project, Guinea. However, we find that there are no earlier records or studies conducted on the use of trail cameras in the monitoring and census of wild gharial populations perhaps due to its highly aquatic nature and small population size. Thus, this study may be considered as pioneering work on the use of trail cameras incorporated as part of a multi-method approach in counting of gharial and would require further refinements.

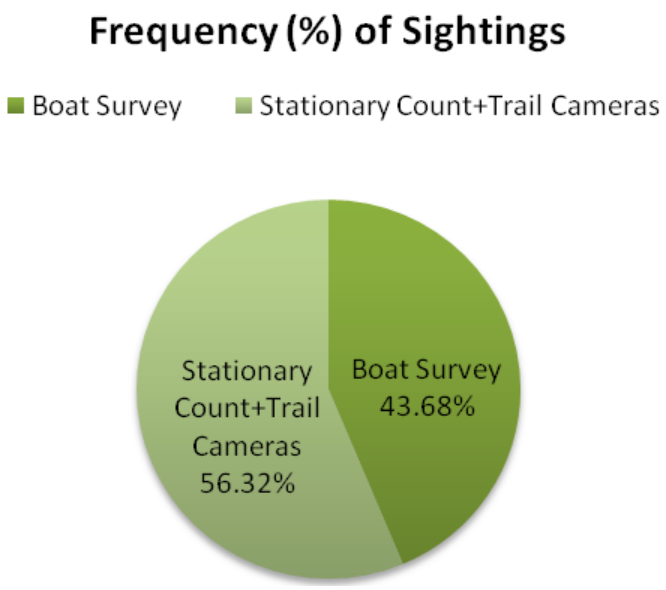
We treated the number of gharial counted viz. number of sightings by Stationary Counts and Trail Cameras as the same (since trail cameras essentially performed the functions of stationary counts) and compared them with the number of sightings from boat surveys on days when all three were conducted simultaneously. It is estimated that 43.7% of our sightings were made during boat surveys and 56.3% of our sightings were made due to the combined effort of stationary counts and trail cameras (Table 6, Graph 2).

Using the maximum ± minimum (MM) method our population estimates for Dhikala was 32 adults (inclusive of 7 adult males). We also considered that an unknown fraction of animals may have been missed during the enumeration work that is presence with non-detection. To determine this "unknown fraction" we subjected our data to a Double Sampling analysis where the mean adult population was estimated as 29 adults from "Intensive Surveys", sample size of three (n=3) followed by a "Rapid Survey" along the Dhikala shoreline during which we estimated the adult population as 27 adults. Probability (p) was calculated from "Intensive Surveys" which had a Variance (S^2) of 7 and Probability (p) was estimated as 0.76 indicating that the population at Dhikala had a positive binomial distribution. To estimate the unknown proportion of adult gharial at Dhikala (presence with non-detection), we used the relation n = c/p, where 'c' was estimated from the Rapid Survey as 27 animals. Thus, n = 27 / 0.76; n = 36 adults (inclusive of 7 adult males).

These results are indicative that we were able to sample an estimated 88.9% (n=32; inclusive of 7 adult males) of the adult gharial population at Dhikala using this multi - method approach of trail cameras, stationary counts and boat surveys along the shoreline.

Based on our three population estimates (n= 29, 32 and 36) we averaged the adult population at Dhikala as 32.3 + 1.69 adults (Mean + SE) with an encounter rate of 4.01 + 0.33 adults km^{-1} over 8.06 km of shoreline.

Further, in comparing population estimates for adults between 2008 and 2013, we used the Maximum ± Minimum (MM) Method, whereby which we estimated that the number of adults in Dhikala increased by 77.8 % between 2008 and 2013 (Table 5).



Graph 2. Frequency (%) of sightings.

Specifically, the adult male population increased by 250% while the adult population increased by 56.25% during this time period in the study area. The adult male: adult ratio in 2008 was 1:8 and in 2013 it decreased to 1:3.57 indicating smaller male-female sex ratios at Dhikala.

To establish whether this increase in the number of adults at Dhikala was only because of population turnover of sub-adults to adults or due to the cumulative effects of population turnover, animals undetected during surveys in 2008 and in-migration into the area , surveys by boat were conducted in areas near the study site which showed presence of gharial sub-populations in 2008 and from where gharial could have possibly in-migrated to Dhikala viz. Gaujeda and the northern periphery of the Kalagarh Reservoir between the Phulai Channel and Gaujeda, with a survey route of 7.91 km (Map 3). In these areas, we estimated 5 adults (inclusive of 2 adult males) in Gaujeda and 5 adults (inclusive of 3 adult males) along the northern periphery of the Kalagarh Reservoir (between the Phulai Channel and Gaujeda) in 2008. In 2013, boat surveys did not record any gharial in these areas indicating that during the study period these adult gharial (n=10) were now possibly congregating at Dhikala (Map 4). This increase in the adult population detected in the study area is therefore likely to be due to a combination of population growth, in-migration of adult gharial and some individual adults being undetected (during the 2008 surveys) in the study area.

In addition, the Corbett National Park is free from many man induced anthropogenic pressures like irrigation canals, artificial embankments, sand mining, harvesting of gharial eggs for food, use of fishing nets in which gharials get entangled and drown, river use by domestic cattle and cultivation of seasonal vegetables at nesting

Table 5. Calculation of percent (straight line) growth rate of adults at Dhikala, CTR based on counts derived from the MM method.

Percent (straight line) growth rate (PR)	Count (2013)	Count (2008)	Calculation
$\frac{C\ (Present) - C\ (Past)}{C\ (Past)} \times 100$ Where, C (Present) = Present count (2013) C (Past) = Past count (2008)	32	18	$PR = \frac{C\ (Present) - C\ (Past)}{C\ (Past)} \times 100$ $PR = \frac{32 - 18}{18} \times 100$ $PR = \frac{14}{18} \times 100$ $PR = 0.7777 \times 100$ $PR = 77.78\%$

Table 6. Number of Sightings.

Parameter	Number of sightings
Boat Survey	38
Stationary count +trail cameras	49
Total number of sightings	87

and basking sites as often seen in other crocodile sanctuaries in the country. Tourism is a regulated activity in the Reserve, with little or no access for tourists to gharial, thereby further reducing disturbance to these animals. However, in the Sonanadi Wildlife Sanctuary of CTR river use of the Palain and Sonanadi Rivers by the *Van Gujjar* pastoralists is well known and may well be affecting gharial populations there. The results indicate that minimal disturbances to the aquatic habitat in CTR particularly in Corbett National Park with no significant man induced anthropogenic pressures is benefitting the gharial population here indicated by the increase in adult gharial numbers at Dhikala.

Limitations

While trail cameras have showed encouraging results further refinements are required in incorporating the use of trail cameras in estimation work with regard to choice of trail cameras, placement and density of trail cameras in the field and data collection protocols and analysis.

Recommendations

1) The establishment of a Monitoring Programme for the taxon in CTR should be given impetus bearing in mind the change of the taxon to Critically Endangered by the IUCN Red List in 2007. Considering the contribution of the CTR meta-population of 20% towards the global population of 200-250 adults, the global decline of the taxon, and the endemism and uniqueness of this meta-population within the region, it is important that such a programme be undertaken annually for a number of years in collaboration with the CTR Authorities.

2) The multi-method approach incorporating the use of trail cameras, boat surveys along the shoreline and stationary counts should be continued with in this part of the Reserve.

The size classification used during the course of this study is recommended as a standard for classifying gharial cohorts for population studies within the Reserve and to compare future counts. Future studies should be planned so as to understand the ecology of the taxon in the reserve in relation to population trends, habitat preferences, size class distribution, and sex ratios.

3) Anthropogenic pressures on the taxon in Corbett National Park are negligible and the overall protection measures implemented in the Reserve, which also include the regulation of tourism in Corbett National Park have also proved beneficial for the taxon should be continued with and not diluted in any manner. In the Sonanadi Wildlife Sanctuary of the Reserve due to river use of the Palain and Sonanadi Rivers by the *Van Gujjar* pastoralists, protection of basking and nesting areas is important. Surveys in these areas should be conducted to monitor gharial populations, to identify nesting and basking sites and to document river use of the *Van Gujjar* pastoralists so that the CTR Authorities may also enforce relevant riverine protection measures effectively in the Sonanadi Wildlife Sanctuary.

ACKNOWLEDGEMENTS

We thank The Columbus Zoo, The CZS CBOT Endangered Species Fund, The PPG Conservation and Sustainability Fund, The Mohamed bin Zayed (MBZ) Species Conservation Fund, WWF - India, The Rufford Small Grants Foundation and Idea Wild for support for

Map 3. Locations of Gharial sub-populations in 2008 at CTR.

Map 4. Areas surveyed for Gharial 2013, in Dhikala, CTR.

this project. Mr. S.S Sharma, IFS, PCCF (Wildlife) / Chief Wildlife Warden, Uttarakhand Forest Department, Mr. Samir Sinha, IFS, CCF and Field Director, Corbett Tiger Reserve, Dr. Saket Badola, IFS, Deputy Director, Corbett Tiger Reserve, Range Forest Officers, Field staff and Office Staff of Corbett Tiger Reserve are thanked for their assistance. We would like to thank The University of Stellenbosch and specially The Gadoli and Manda Khal Wildlife Conservation Trust for its continuing support. A special thanks to the Anonymous Reviewers for Review of this Manuscript and for their valuable suggestions which have helped in bringing this manuscript into its present form.

REFERENCES

Basu D (2008). pers. comm.
Choudhury BC, Singh LAK, Rao RJ, Basu D, Sharma RK, Hussain SA,

Andrews HV, Whitaker N, Whitaker R, Lenin J, Maskey T, Cadi A, Rashid SMA, Choudhury AA, Dahal B, Win Ko Ko U, Thorbjarnarson J, Ross JP (2007). *Gavialis gangeticus*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 20 October, 2013

Chowfin MS (2010). Gharial Estimation and Habitat Assessment Survey 2008, Corbett Tiger Reserve, Uttarakhand, India, Project Report Submitted to the PCCF (Wildlife), Uttarakhand Forest Department

Chowfin MS (2011). Gharial Estimation and Habitat Assessment Survey, Corbett Tiger Reserve, Uttarakhand, India: Field Survey Report; Cheetal 49(3):96-104.

Chowfin MS, Leslie AJ (2013). A preliminary investigation into nesting and nest predation of the critically endangered, gharial (*Gavialis gangeticus*) at Boksar in Corbett Tiger Reserve, Uttarakhand, India. Int. J. Biodivers. Conserv. 5(2):54-57.

Larrucea ES, Serra G, Jaeger MM, Barrett RH (2007). Censusing Bobcats using Remote Cameras. Western N. Am. Nat. 67(4):538-548.

Messel H, Vorlicek GC, Wells AG, Green WJ (1981). 'Surveys of Tidal River Systems in the Northern Territory of Australia and their Crocodile Populations. Monograph 1. The Blyth-Cadell Rivers system study and the status of Crocodylus porosus in tidal waterways of northern Australia.' Pergamon Press: Australia. pp. 454-459.

Ogurlu Idris; Ertugrul Emarah Tagi and Unal Yasin (2013). Research on the efficiency and performance of camera traps and dome system for wild goat inventory. Afr. J. Environ. Sci. Technol. 7(5):229-235.

Rao RJ, Basu D, Hasan SM, Sharma BB, Molur S, Walker S (1995). Population and Habitat Viability Assessment Workshop (P.H.V.A.) Workshop for Gharial Report.

Seijas, A. E and Chavez C. (1999), Population status of the Orinoco crocodile (Crocodylus intermedius) in the Cojedes river system, Venezuela. Biological Conservation 94 (2000). pp 353-361.

Somaweera R, Webb JK, Shine R (2011). It's a dog-eat-croc world: dingo predation on the nests of freshwater crocodiles in tropical Australia. Ecol. Res. 26 (5):957-967.

Tobler MW, Carrillo-Percastegui SE, Leite Pitman R, Mares R, Powell G (2008). An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. Anim. Conserv. 11(3):169-178

Web Sources: The Wildlife Chronicles (www.subirchowfin.blogspot.com).

Whitaker R (1979). The Crocodilians of Corbett National Park. Indian J. For. 2(1):38-40.

Whitaker R, Members of GMTF (2007). The Gharial: Going extinct again. Iguana 14 (1):25-33

academicJournals

Vol. 6(2), pp. 171-183, February 2014
DOI: 10.5897/IJBC2013.0647
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJB

International Journal of Biodiversity and Conservation

Full Length Research Paper

Developing macrohabitat models for bats in parks using maxent and testing them with data collected by citizen scientists

Jessica Buckman-Sewald*, Christine R. Whorton and Karen V. Root

217 Life Sciences, Bowling Green State University, Bowling Green OH 43403, United States of America.

Accepted 03 December, 2013

Protected areas may function as islands of habitat in otherwise adverse environments for many species of North American animals. It is currently unclear how to maintain suitable foraging habitat for bats within these areas. Bats are nocturnal and highly mobile, making their specific needs difficult to determine. Using data collected from acoustically surveyed sites within protected areas in the Oak Openings Region of Northwest Ohio, a biodiversity hotspot, we developed spatially explicit macrohabitat models using maximum entropy modeling (Maxent). We then used data collected by citizen scientists to test these models to determine their success in predicting species presence. We found that the models were successful (AUC values > 0.75) at predicting the occurrence of the seven species for which models were developed, *Lasionycteris noctivagans*, *Lasiurus borealis*, Lasiuruscinereus, *Myotis lucifugus*, *Myotiss eptentrionalis*, *Nycticeius humeralis*, and *Perimyotis subflavus*. Within protected areas, it is important to manage for heterogeneous habitat composition at this intermediate scale to maintain potential for foraging areas for all occurring bat species. Data collected by citizen scientists is useful to test spatially explicit models and can potentially be used to monitor long term changes in bat species composition in these systems and across regions.

Key words: Bats, maxent, northwest Ohio, citizen science, parklands.

INTRODUCTION

Studies on the activity of bats in the summer are often based in areas that are relatively forested and intact (Brigham, 2007). However, data on activity in systems typified by habitat loss and urbanization are lacking (Avila-Flores and Fenton, 2005; Dixon, 2011; Duchamp et al., 2004; Gehrt and Chelsvig, 2003, 2004; Sparks et al., 2005). Evidence from more thoroughly studied species suggests, however, that activity will differ depending on the landscape context (Estes and Mannan, 2003).

Within human dominated systems, protected areas for example metroparks and parkland, exist in pockets of relative isolation (Donnelly and Marzluf, 2004; Rothley et al., 2004) surrounded by a potentially hostile matrix of development and agriculture. How bats utilize protected areas is unclear, but studies have demonstrated higher species diversity inside parks compared to outside of them (Avila-Flores and Fenton, 2005; Duchamp and Swihart, 2008; Glendell and Vaughn, 2002; Jung and Kalko, 2011). This suggests that protected areas may serve as a critical refuge from human-mediated impacts

*Corresponding author. E-mail: jessicasewald@missouristate.edu.

(Glendell and Vaughan, 2002; Loeb et al., 2009).

It is important to identify the characteristics of these parks and their context that promote long-term viability of native species. Additionally, there may be more variability in bat activity and presence within a park than between parks (Gehrt and Chelsvig, 2003, 2004; Johnson et al., 2008) and species diversity may be lower in urban rather than rural parks (Johnson et al., 2008; Kurta and Teramino, 1992; Loeb et al., 2009). Some of these findings may also reflect the variability of individual species for specific habitat characteristics (Lacki et al., 2007) as a result of different morphology and echolocation abilities (Aldridge and Rautenbach, 1987). In general, these species-specific differences are predictive of where a bat will forage, but this may vary depending on the location (Kurta and Whitaker, 1998) or species may show plasticity in their foraging (Ratcliffe and Dawson, 2003).

To determine potential effects of management, habitat changes, and prioritizing areas for protection, we need to understand these differences in species distributions and behavior. Previous models for predicting bat distributions have often been conducted at the landscape scale, which by their nature are relatively coarse, placing up to 1 km buffers around survey points (Ford et al., 2006). A focus on this large scale provides limited insight into the characteristics of the area immediately surrounding the foraging environment and this intermediate macro habitat (Saab, 1999) scale is often the target of management within protected areas (Abella et al., 2001).

To address this need, we relied on acoustic surveys to determine bat presence at the macrohabitat scale. Acoustic surveys can be conducted in areas where capturing bats with the traditional method of mist netting is difficult (that is within parks). The present data collected by acoustics has been successfully used to model species presence in association with habitat characteristics in a number of other studies (Brooks and Ford, 2005; Erickson and West, 2003; Ford et al., 2005; Ford et al., 2006;Francl et al., 2004; Johnson and Gates, 2008; Loeb and O'Keefe, 2006; Zimmerman and Glanz, 2000).

Linking species data to the associated habitat characteristic relies on any number of statistical approaches depending on the sample sizes and the structure of the data. We chose to use maximum entropy modeling in the program Maxent to build predictive habitat models based on presence of bats detected through acoustic monitoring. Maximum entropy modeling and the program Maxent is a way to model species distribution using presence data (Phillips et al., 2006) with small sample sizes (Hernandez et al., 2006; Kumar and Stohlgren, 2009). Although we had absence data for our sites, the data can be misleading as we cannot be confident that these are true absences (Anderson, 2003). Maxent has been used to successfully model the distributions of a range of taxa: plants (Schetter, 2012; Kumar and Stohlgren, 2009), exotic ant species (Ward et al., 2007), birds (Elith et al., 2006), geckos (Pearson et al., 2007), as well as African (Lamb et al., 2008), Asian (Hughes et al., 2012), and European (Rebelo et al., 2010) bats. The program takes the user-defined environmental layers within a geographic area and estimates the probability distribution of maximum entropy (or closest to uniform). This approach allows us to maximize the use of our acoustic data while minimizing the assumptions necessary.

In most modeling situations, a subset of the originally collected data is withheld and then used to test (testing data) the model. We chose instead to use a novel approach of testing the model with a data set collected by citizen science volunteers. In this way, we demonstrate that data collected by citizen scientists can be used as an effective independent test of the model and increase our confidence in its application (Guisan and Zimmerman 2000). The data collected by citizen scientists are also easily added to the program Maxent and analyzed using "Area Under the Curve" (AUC) of a "Receiver Operating Characteristics" (ROC).

Acoustic surveys of bats conducted by volunteers have been a way of monitoring bat trends in England for a number of years (Walsh et al., 1993), but have not been widely used in the United States. The original goals of citizen science programs were education and outreach, but large amounts of scientifically useful data can also be collected (Bonney et al., 2009). Examples of this abound in the United States in which large scale studies of birds are quite successful (Lepczyk, 2005). Citizen science is now increasingly used in studies from classifying star systems (Raddick et al., 2010) and monitoring seismic activity (Cochran et al., 2009) to wildlife sightings on major roads (Lee et al., 2006).

Our goals were to develop a macrohabitat model of bat presence for all occurring bat species at the macrohabitat level using Maxent, and then demonstrate the usefulness of testing these models with data collected from citizen scientists.

MATERIALS AND METHODS

Study area

The Oak Openings Region of Northwest Ohio (located in the north central portion of the United States) is a 476 km² area characterized by soil types from post glaciation events and contain a heterogeneous mix of habitats including vulnerable or imperiled plant communities (Noss et al., 2005) such as the critically endangered oak savanna (Brewer and Vankat, 2004). Considerable fragmentation has occurred due to increased urbanization and agricultural expansion (Brewer and Vankat, 2004) (Figure 1). This region remains an area of high biodiversity and protected areas within the region are considered critical stopover locations for migrating birds (Ewert et al., 2005) and potentially bats (V. Bingman, personal communication).

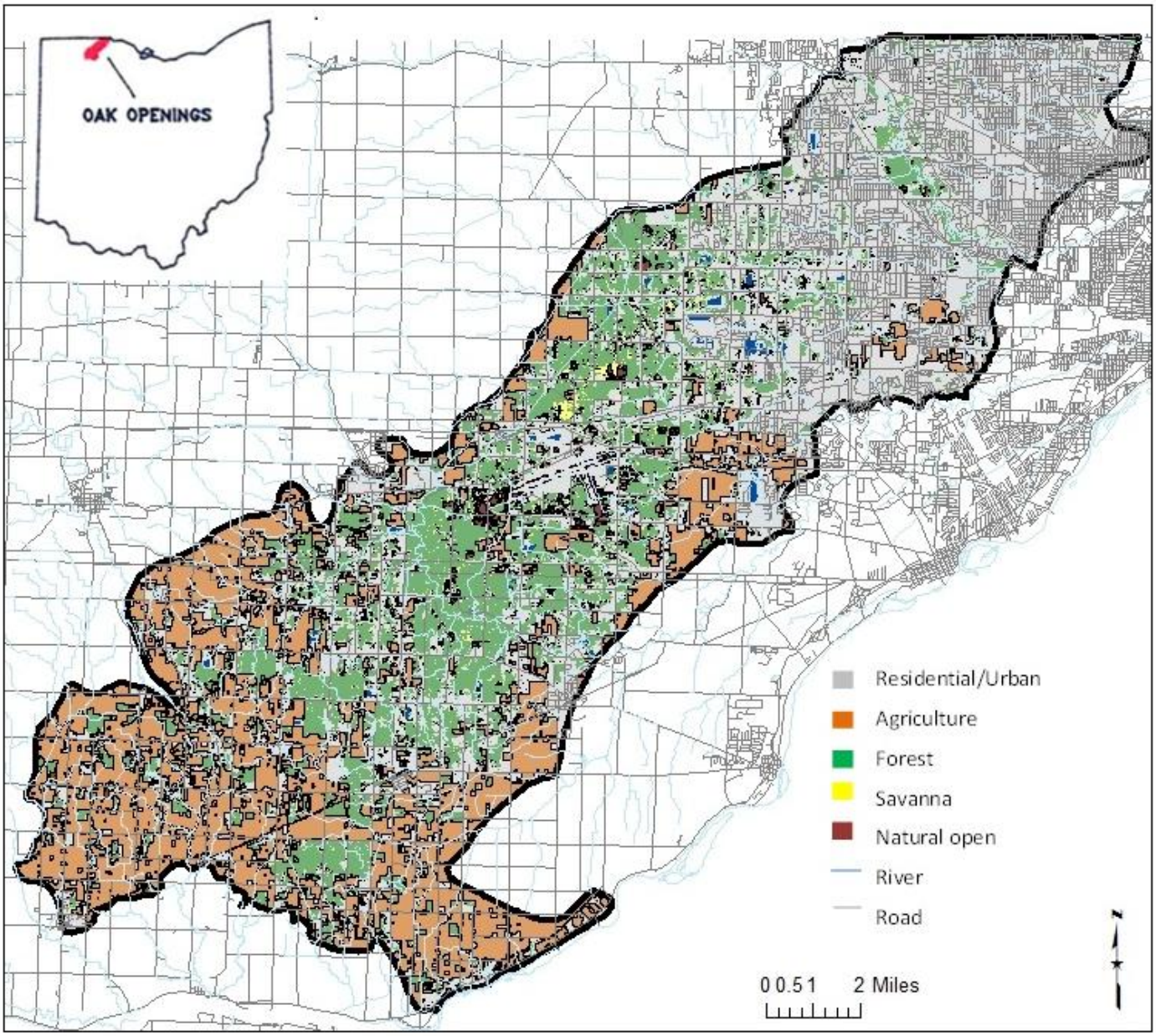


Figure 1. Map of the Oak Openings Region showing the extent of fragmentation caused by roads (lines), agriculture and urban areas (inset of location within Ohio).

Acoustic monitoring to determine species presence

From June 1st to September 2nd, 2009, we acoustically surveyed 32 sites five times each with a broadband acoustic device (Anabat, Titley Electronic, Ballina, New South Wales, Australia). These sites were within two of the main protected areas within the region, an area of 1722 ha, comprising approximately 10% of the natural area remaining. These protected areas are owned and maintained by the Metroparks of The Toledo Area and are both within Lucas County, Ohio. Sites within these parks were chosen because they encompassed all described habitat types (Ford et al. 2005, Loeb and O'Keefe, 2006) and were within 0.5 km of water, which all bats rely on to varying degrees (Francl, 2008; Vaughan et al., 1997).

Methods of echolocation monitoring followed those previously well established (Brooks and Ford, 2005; Brooks, 2009; Johnson and Gates, 2008; Johnson et al., 2008; Ford et al., 2005; Ford et al., 2006;Francl et al., 2004;Francl, 2008) for acoustic monitoring. Four sites within a quarter of a mile to each other were surveyed in the same night and each was actively surveyed for 20 minbefore moving onto the next site. Monitoring began approximately 0.5 h after sunset and ended 3 h thereafter, covering the time frame when bat activity is most homogeneous (Hayes, 1997). All sites

were greater than 100 m apart, which is well outside the reception area of the Anabat (Livengood, 2003). We also avoided sampling during times of strong wind (for example > 3 on Beaufort scale) or rain.

All files with more than three identifiable calls were analyzed and taxa determined (by the primary author who compared calls to a known call library) to species level, both qualitatively (Analook version 3.7w), and quantitatively (Allen, Bat Call Identification version 2.0.5.2, Kansas City, MO). When the two methods disagreed on identification, the call file was qualitatively inspected again and the primary author determined identification. Each species was considered present if it was detected at least once during the five surveys at a given location.

Macrohabitat characteristics

We derived macrohabitat characteristics using ArcMap 9.2 software (ESRI, Redlands, California, USA). The original landcover map for the Oak Openings Region was developed by Schetter and Root (2011) using 30 m pixel Landsat data and contains a total of 15 different land classes, including asphalt, turf, residential, swamp, floodplain and upland forest, savanna, wet prairie, prairie, barren, meadow, shrub/scrub, conifer, crop and pond. We excluded wet prairie, barren, shrub/scrub and conifer cover in further analysis due to their low sample size and relatively low frequency within the Oak Openings Region.

We used the program FRAGSTATS (McGarigal and Marks, 1995) and a 60 m circular moving window to determine the percentage of land cover type around each 30 m pixel as well as measures of fragmentation including cohesion, number of patches, landscape shape index, and the Simpson diversity index for types of land cover. We also determined distance to nearest road, stream (US Census Bureau, 2009), residential and agricultural area.

Model development

We first ran correlation analysis on all environmental variables and those that were correlated $r > 0.6$, $p<0.05$ were assessed and variables chosen a priori to decrease overfitting due to model complexity (Merow et al., 2013). Distance to residential area, distance to roads, and the percentage of residential cover were all correlated. We chose to use distance to roads in all models since roads are a critical feature that indicate human influence on the landscape. Roads may also facilitate unimpeded movement, or foraging, as ditches (which may be used as alternative water and feeding sites, Vindigni et al., 2009) are commonly adjacent to most major roads in the area. Measures of fragmentation and heterogeneity were also found to be highly correlated so we only included the number of habitat patches as a general measure of fragmentation in model development.

For all species, we included distance to stream, and distance to agriculture, as these variables have been found to be important for bats in general (Yates and Muzika, 2006; Either and Fahrig, 2011; Grindal et al., 1999) and particularly those in urban/agricultural matrices (Gehrt and Chelsvig, 2004; Duchamp and Swihart, 2008). We retained all measures of forest for example upland, swamp and floodplain) and open cover (for example meadow and prairie), as well as savanna because of its unique status in this region

To decrease the issues surrounding spatial autocorrelation (Veloz, 2009), we employed the methods of Parolo et al. (2008) for species in which we had greater than 15 presence points (northern Myotis, little brown bat and eastern red bat). We used GIS to determine the distance of each presence point from each other and randomly removed presence points within a threshold distance (30% of locations closest to each other). We chose not to remove presence points for the remaining species, choosing instead to maximize sample size, with the understanding that some overfitting in the models may occur fo rthose species.

We ran ten replicates with the default settings (Phillips and Dudik, 2008) in the Maxent program (v.3.3.3k, Phillips et al., 2006) to develop habitat distribution models for each bat taxon that was recorded during our acoustic surveys. The model outputs were on a logistic scale in which each map pixel was assigned a number between 0 (low habitat suitability) and 1 (high habitat suitability). Each model was then combined into an overall species richness model. This was done by summing the model output for each of the seven species with a resulting map made up of pixels ranging in number from zero to seven. A zero represents no species likely present, while a seven would be all species likely present. Our methodology did allow us to gather absences but due to the potential pitfalls of absence data (Anderson, 2003) we chose to use the Maxent method which uses only the presence points. However, we also conducted Wilcoxon-signed rank tests between the presence and absence of each species in association with the environmental variables to further support the Maxent models.

Model testing

From June1th-August 15thof 2011, a citizen science program held in conjunction with the Metroparks of the Toledo Area was initiated. Volunteers walked along ten park trails that occurred within two parks where data was originally collected, and two smaller areas not previously surveyed. Volunteers were trained on the use and how to hold the acoustic monitor while walking and the pace at which to walk. Volunteers began walking the trails between 15 minand a half hour after sunset and concluded 45 min to 1 h later. Each trail was surveyed between one and five times. This program was continued in 2012, and nine of the ten original trails were monitored using the same protocol as the previous year.

The data for each species along volunteer-monitored trails were used to test the relevant macrohabitat model. GPS coordinates corresponding to the detection of each species were taken and entered into Maxent as test data. The model performance in terms of the test data was evaluated using ROC curves. ROC curves balance both omission and commission errors in a model set generating a graph line that represents a random level of performance (Fawcett, 2006). The AUC are between 0 and 1 and values of 0.5 are considered a random prediction (Fawcett, 2006). A second evaluation of the test data given by the Maxent program is a threshold dependent evaluation (ROC is threshold independent). This uses a χ^2 test to determine the difference between the proportions of predicted area generated by the model, versus what would be predicted from random (Phillips et al., 2006).

RESULTS

Species detected

During the initial 2009 surveys, a total of 1,570 call files were recorded and identified to species. Species detected included big brown (*Eptesicus fuscus*) (1,195 files), Eastern red (*Lasiurus borealis*) (118 files), little brown (*Myotis lucifugus*) (81 files), tri-colored (*Perimyotis subflavus*) (54 files), Northern *Myotis* (*Myotiss eptentrionalis*) (39 files), silver-haired (*Lasionycteris*

Table 1. Percentage of contribution of ten environmental variables to maxent species distribution models developed within the Oak Openings region for each of seven species of bats.

Environmental variable	Northern myotis	Little brown	Tri-colored	Evening	Silver-haired	Eastern Red	Hoary
Distance to roads (m)	0 +	1 +	0.1 n	0.3n	0 +	0 n	0.1 n
Distance to agriculture (m)	12.8 +/-	25.6+/-	16 +/-	12 +	1.3 -	13.2 +/-	1.2 n
Distance to water (m)	42.1 -	23.5 -	56.5 -	37.9 -	64.4 -	28.4 -	49.2 -
Floodplain forest (%)	8.3 +	12.1 +	5.4 +	0 n	0.8 +	1 +	0 n
Swamp forest (%)	0.1 +/-	0 +/-	1.2 n	9.8 -	0.1 n	0.2 -	0 n
Upland forest (%)	35.0 +	32+	1.5 +	12.5 +	0.2 +	17.2 +	27.5 +
Number of patches	1 n	0.1 +	1.6 +	17.9 +	14.4 +	4 +	2.8 n
Prairie (%)	0.2 -	0.7 +/-	11.3 +	1.5 +	0.2 +	11.8 +	0.3 +
Meadow (%)	0.6 -	1.1 +	0.6 n	2.8 +	9.2 +	5.6 +	18.6 +
Savanna (%)	0.1 -	4.1 +	5.8 +	5.3 +	9.5 +	18.4 +	0.3 -

Symbols that follow each percentage indicate the response curve given to each environmental variable by Maxent. “+” indicates increasing, “-“ indicates decreasing, “+/-“ indicates an initial increase followed by a decrease and “n” is no change.

noctivagans) (34 files), hoary (*Lasiurus cinereus*) (26 files), and evening (*Nycticeius humeralis*) (23 files) bats. Three files keyed out to the endangered Indiana bat (Myotis sodalis), but because of the difficulty of distinguishing the calls of this species from the little brown bat (Britzke et al., 2002), we could not definitively determine its presence.

Big browns have been found to be ubiquitous in many urban situations (Loeb et al., 2009; Johnson et al., 2008), and we had similar results. Big browns were present in every location in both the originally collected data and the citizen science collected data; therefore we dropped them from further habitat modeling since there was no difference in occupancy across the surveyed sites any resulting model would include all similar natural areas. The remaining seven species were present at a low of five sites for the hoary bat to a high of 19 sites for the little brown bat.

Habitat models

The percentage of contribution of the ten environmental variables to the Maxent models are shown in Table 1, while Figure 2a and b show the suitable area for each species. Those environmental factors associated with urban/agricultural areas, including distance to roads, distance to agriculture and the number of patches, had varying importance in models for each species.

Presence of Northern myotis, little brown, tri-colored and eastern red bats were most likely at intermediate distances from agriculture. Distance to roads provided a negligible contribution to all models, while the number of different habitat patches contributed to the models for evening, eastern red and silver-haired bats. The distance to water provided a large contribution to models for all seven species and presence was more likely closer to water, although this difference was not as evident when looking at only the results of the Wilcoxon-signed rank test (Tables 1 and 2). The type of forest covers that contributed to each species model generally aligned with expectations for that species based on previous literature.

Northern myotis and little brown bat models had contributions from upland forests. Open adapted bats (silver-haired, eastern red and hoary) had combi-nations of contributions resulting from upland forest, prairie, meadow and savanna.

The developed models for all seven species were significantly better than random when considering the threshold dependent χ^2 test at the 1, 5 and 10% omission thresholds (a proxy measure for the amount of suitable habitat misclassified as unsuitable), as well as when commission and omission rates are balanced (Table 3).

In all cases, the models were significantly better than a random model at predicting suitable habitat. The predicted amount of suitable habitat at the 10% threshold ranges from a low of 30% for the little brown bat to a high of 48% for the hoary bat. The multi-species model (Figure 3) demonstrates overlap in locations throughout the Oak Openings Region that are potentially suitable for all seven species.

The models using the training data all exceeded the “very good” threshold of 0.9 based on the threshold independent AUC tests (Swets, 1988); however, only two models using the test data met this threshold (Table 3) (evening and eastern red bats). The remaining models using the test data were still well above the cut-off of 0.75, though, which indicates that the discrimination ability of the model was still considered useful (Elith et al., 2006).

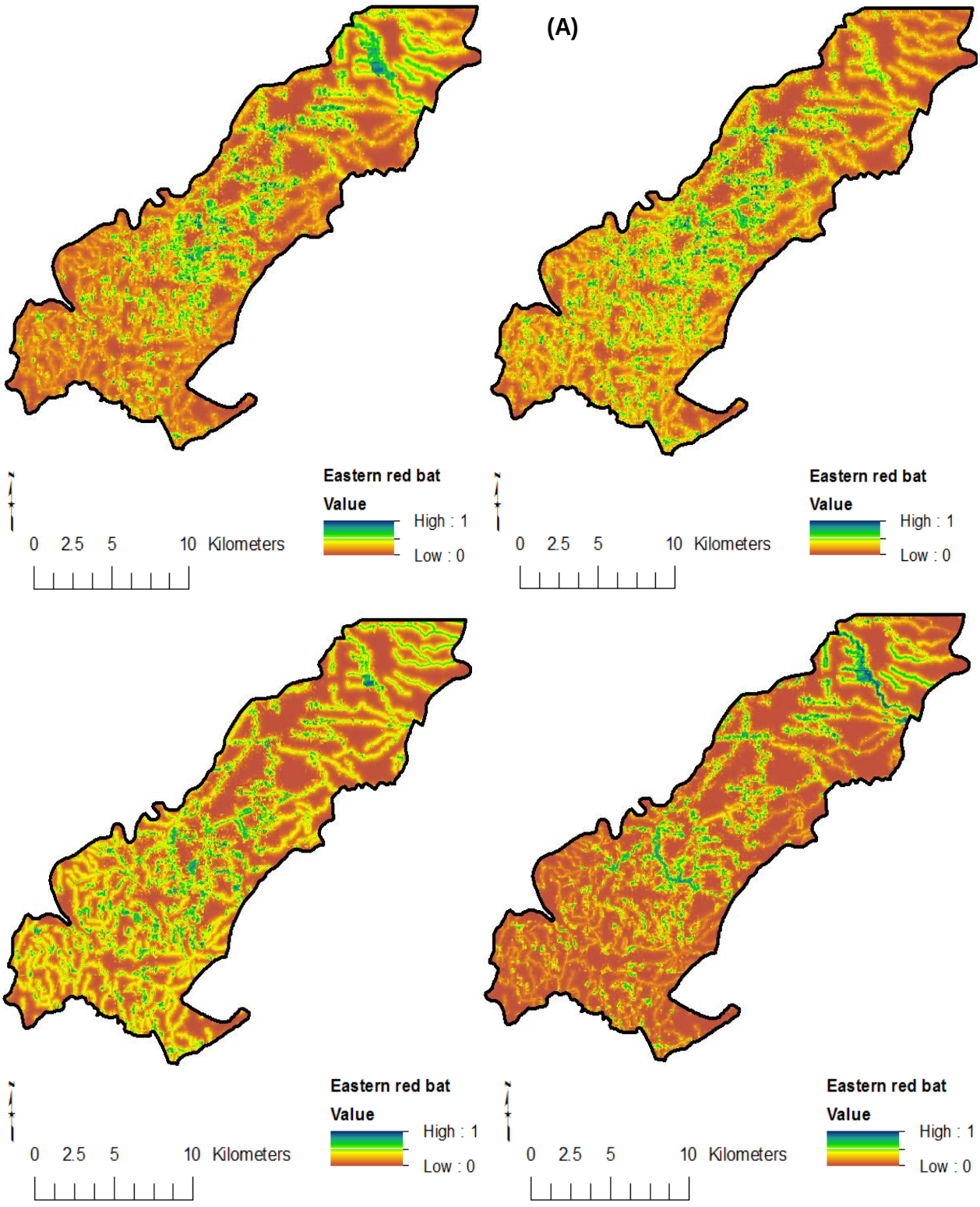


Figure 2. (A) Maxent model results for the four species that are considered open adapted of the bats within the Oak Openings Region of Northwest Ohio including silver-haired, red, tri-colored and hoary bat. Map showing both the full extent of the Oak Openings and that within protected areas. **(B)** Maxent model results for the three species that are considered forest adaptedof the bats within the Oak Openings Region of Northwest Ohio,including little brown, northern Myotis and Evening bats. Map showing both the full extent of the Oak Openings and that within protected areas.

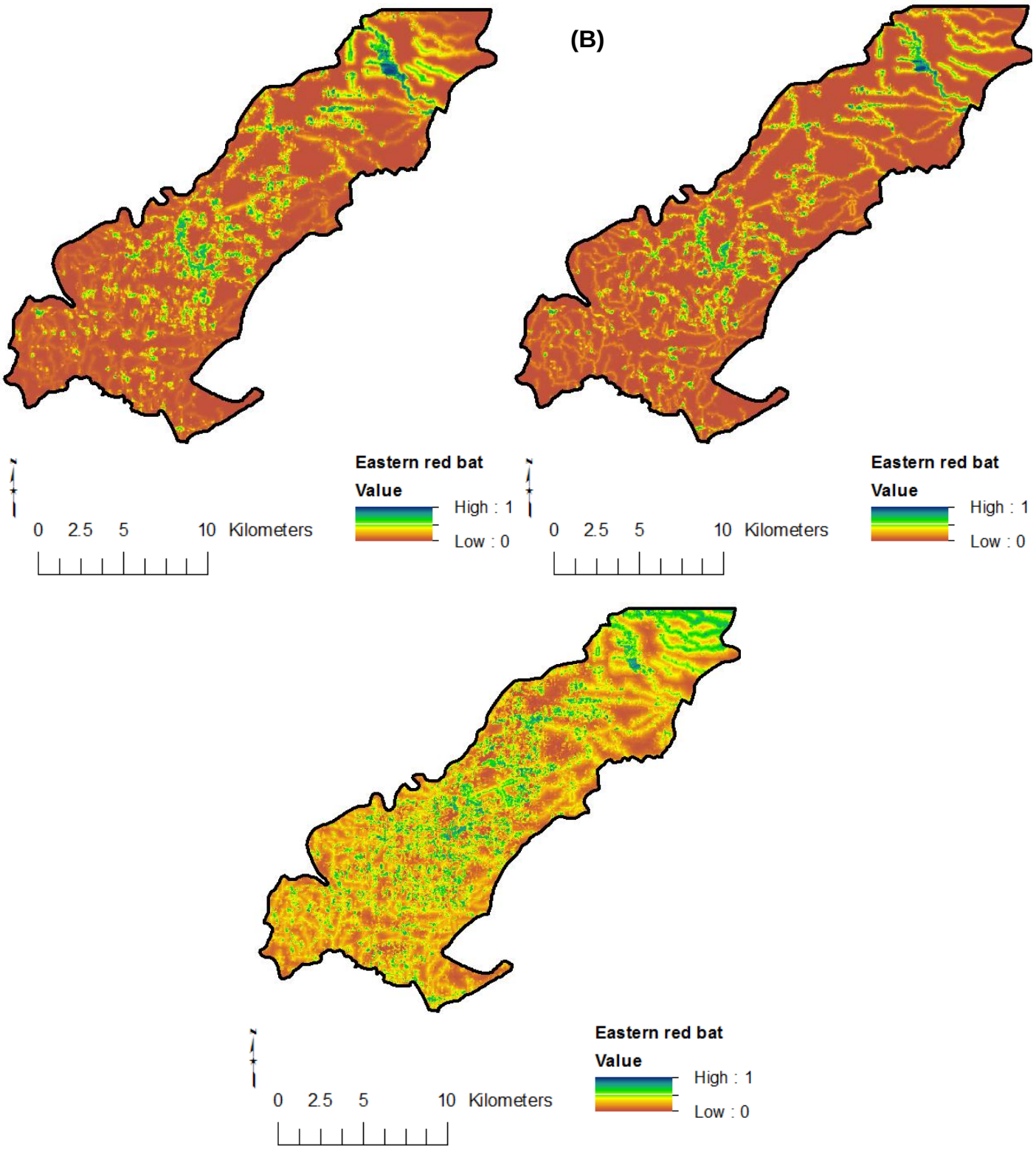


Figure 2. Contd.

Table 2. Wilcoxon-signed rank test between the presence and absence of seven bat species across ten environmental macrohabitat variables. Tests were conducted on data collected at 32 acoustic survey sites in two protected areas within the Oak Openings Region in 2009.

Parameter	Present			Absence			z	p.
	Mean	SE	n	Mean	SE	n		
Northern Myotis								
Number of patches	3.38	0.44	10	4.13	0.44	16	0.997	0.31
Distance to Agriculture (m)	2221.63	324.24		1516.25	324.24		-1.451	0.14
Distance to road (m)	235.09	38.07		238.98	38.07		0.169	0.86
Distance to water (m)	75.19	26.03		174.14	26.03		2.129	0.03
Floodplain forest (%)	29.69	6.22		15.81	6.22		-1.23	0.21
Swamp Forest (%)	13.06	3.63		4.81	3.63		-1.088	0.27
Upland Forest (%)	37.31	8.82		29.00	8.82		-0.618	0.53
Meadow (%)	1.44	5.02		12.50	5.02		1.431	0.15
Prairie (%)	0.48	2.35		8.65	2.35		2.429	0.01
Savanna (%)	0.00	4.05		13.13	4.05		2.355	0.01
Little brown								
Number of patches	3.64	0.38	22	4.00	0.57	10	0.558	0.57
Distance to Agriculture (m)	2190.77	267.29		1160.90	396.45		-1.484	0.13
Distance to road (m)	242.23	32.42		225.62	48.09		-0.386	0.69
Distance to water (m)	116.94	24.60		141.66	36.48		0.304	0.76
Floodplain forest (%)	24.55	5.49		18.80	8.14		-0.852	0.39
Swamp Forest (%)	9.50	3.22		7.70	4.78		-0.563	0.57
Upland Forest (%)	34.18	7.57		30.90	11.23		-0.020	0.98
Meadow (%)	8.39	4.42		3.85	6.56		0.257	0.79
Prairie (%)	3.49	2.17		6.92	3.21		1.230	0.21
Savanna (%)	7.55	3.73		4.40	5.54		0.225	0.82
Tri-colored bat								
Number of patches	3.83	0.52	12	3.70	0.40	20	0.455	0.64
Distance to Agriculture (m)	2068.33	386.15		1749.30	299.11		0.506	0.61
Distance to road (m)	175.63	41.61		273.88	32.23		-1.849	0.06
Distance to water (m)	85.21	32.21		148.34	24.95		-1.966	0.04
Floodplain forest (%)	36.83	6.73		14.30	5.21		2.009	0.04
Swamp Forest (%)	8.25	4.37		9.35	3.38		-0.292	0.77
Upland Forest (%)	17.42	9.59		42.60	7.43		-2.054	0.03
Meadow (%)	3.20	5.96		9.23	4.62		0	1
Prairie (%)	5.13	2.97		4.23	2.30		0.102	0.91
Savanna (%)	2.75	4.99		8.85	3.87		-0.892	0.37
Evening bat								
Number of patches	4.10	0.57	10	3.59	0.38	22	0.765	0.44
Distance to Agriculture (m)	2016.80	424.76		1801.73	286.37		-0.040	0.96
Distance to road (m)	143.31	43.51		279.64	29.34		-2.337	0.01
Distance to water (m)	156.94	35.98		109.99	24.26		1.158	0.24
Floodplain forest (%)	14.30	7.97		26.59	5.38		-1.039	0.29
Swamp Forest (%)	2.20	4.55		12.00	3.07		-1.573	0.11
Upland Forest (%)	26.50	11.14		36.18	7.51		-0.687	0.49
Meadow (%)	13.85	6.42		3.85	4.33		1.511	0.13
Prairie (%)	8.46	3.14		2.80	2.12		2.059	0.03
Savanna (%)	10.00	5.50		5.00	3.71		0.482	0.62

Table 2. Cond.

Silver-haired bat								
Number of patches	4.64	0.51	11	3.29	0.37	21	2.180	0.02
Distance to Agriculture (m)	1042.64	360.97		2301.76	261.25		-2.440	0.01
Distance to road (m)	209.29	45.49		251.57	32.92		-0.476	0.63
Distance to water (m)	126.86	34.96		123.52	25.30		-0.515	0.60
Floodplain forest (%)	23.00	7.81		22.62	5.65		0.953	0.34
Swamp Forest (%)	9.00	4.57		8.90	3.31		-0.068	0.94
Upland Forest (%)	19.00	10.23		40.57	7.40		-1.504	0.13
Meadow (%)	18.18	5.76		1.10	4.17		2.291	0.02
Prairie (%)	9.09	2.93		2.20	2.12		1.774	0.07
Savanna (%)	8.00	5.29		5.81	3.83		1.067	0.28
Eastern red bat								
Number of patches	4.00	0.41	19	3.38	0.49	13	-1.073	0.28
Distance to Agriculture (m)	1719.58	306.08		2087.23	370.03		1.247	0.21
Distance to road (m)	194.91	32.79		298.60	39.64		1.880	0.06
Distance to water (m)	127.39	26.59		120.68	32.15		0	1
Floodplain forest (%)	20.89	5.92		25.46	7.15		0.019	0.98
Swamp Forest (%)	7.53	3.45		11.00	4.17		1.285	0.19
Upland Forest (%)	28.47	8.04		40.00	9.72		0.727	0.46
Meadow (%)	8.10	4.78		5.33	5.77		-0.910	0.36
Prairie (%)	7.28	2.23		0.59	2.69		-1.943	0.05
Savanna (%)	10.47	3.87		0.85	4.68		-1.092	0.27
Hoary bat								
Number of patches	3.40	0.81		3.81	0.35		-0.448	0.65
Distance to Agriculture (m)	1914.20	602.39		1860.56	259.23		-0.415	0.67
Distance to road (m)	245.14	68.09		235.54	29.30		0.3633	0.71
Distance to water (m)	90.83	51.43		130.93	22.13		-0.571	0.56
Floodplain forest (%)	15.40	11.49		24.11	4.94		-0.318	0.75
Swamp Forest (%)	4.40	6.71		9.78	2.89		-0.779	0.43
Upland Forest (%)	37.60	15.87		32.33	6.83		0.478	0.63
Meadow (%)	23.08	8.76		3.99	3.77		1.683	0.09
Prairie (%)	4.61	4.60		4.56	1.98		0.648	0.51
Savanna (%)	0.00	7.75		7.78	3.33		-0.985	0.32

DISCUSSION

For seven bat species that occur within the Oak Openings Region of Northwest Ohio, we successfully developed a macrohabitat model that predicted presence in the protected areas and increased our understanding of critical habitat components. We developed models at an intermediate habitat scale that can be used in a straightforward manner; give us a better understanding of where bats are present within a rural/urban landscape; and aid in managing those areas.

This work demonstrates the usefulness of citizen science collected data in testing a spatially explicit model. Despite limitations of where volunteers could go and how often trails could be walked, we were able to gather sufficient testing data in a relatively short amount of time with minimal intrusion on either land management activities or the bats themselves

Test data collected independently of the training data is imperative if we are to understand the generalizability of habitat models (Vaughan and Omerod, 2005). Gathering these data can be expensive and time consuming.

In contrast, employing volunteers in citizen science data collection is relatively inexpensive and provides an opportunity to gather large data sets across space and time (Reisch et al., 2013). This volunteer program has

Table 3. Results of maxent models and "area under the curve" ROC analysis for each of seven species of bats within the oak openings region of northwest Ohio. Also displayed are the percent of predicted suitable area under 1, 5 and 10% omission thresholds of the test data.

Parameter	Northern myotis	Little brown	Tri-colored	Evening	Silver-haired	Eastern red	Hoary
Training AUC	0.978	0.983	0.959	0.983	0.95	0.956	0.974
Test AUC	0.83	0.86	0.855	0.93	0.819	0.845	0.835
1%	71%	69%	75%	79%	84%	84%	78%
5%	50%	46%	51%	58%	66%	64%	60%
10%	38%	30%	38%	43%	53%	50%	48%

The original acoustic data was used to determine the training AUC and this was what was used to develop the model. The test AUC used the citizen science collected acoustic data. Maxent statistically compares test data against a random prediction with the same fractional predicted area. All test data was significantly better than random at the <0.001 level for all omission thresholds.

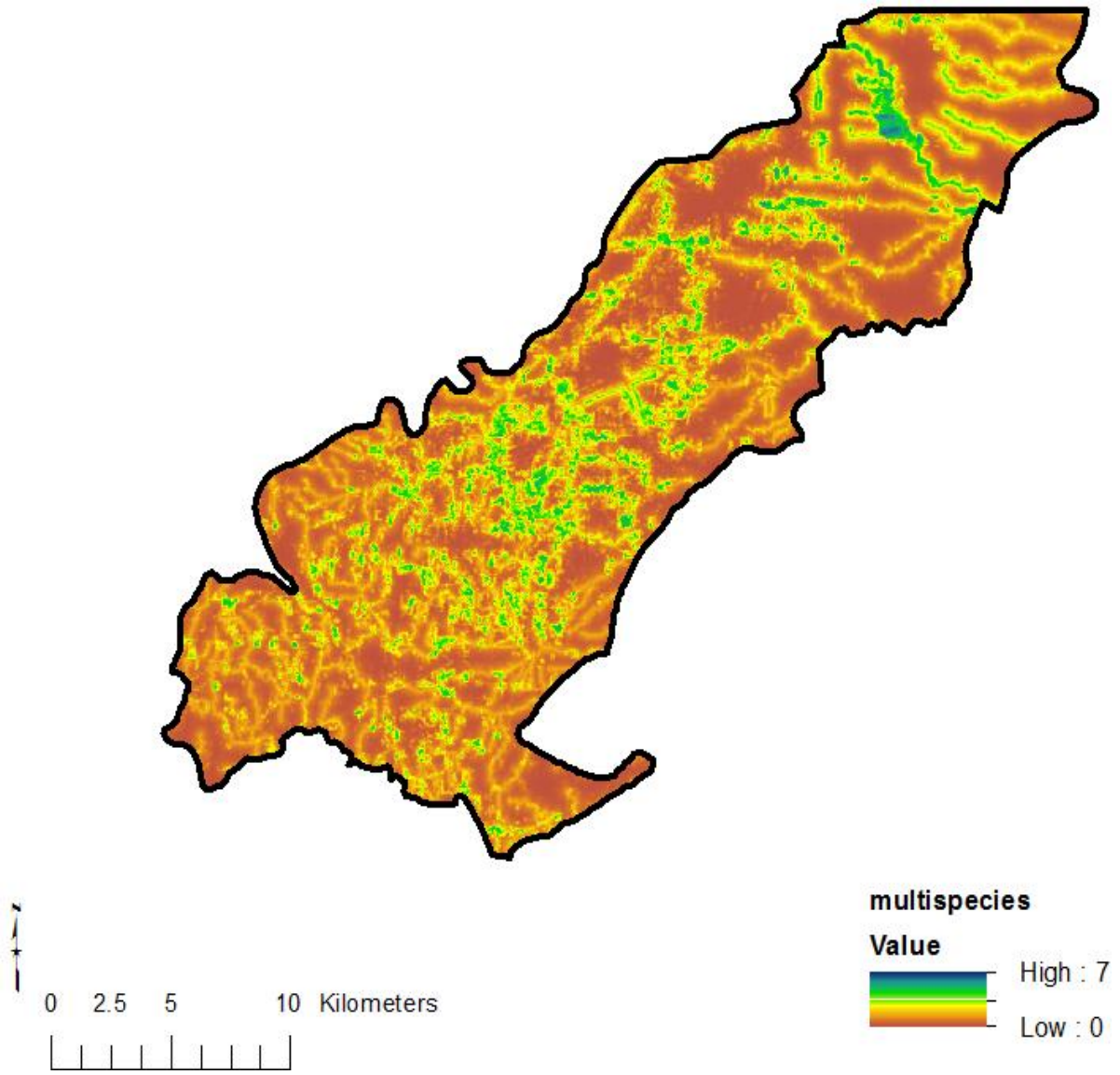


Figure 3. Multispecies bat model with all protected areas indicated within the Oak Openings. Region of Northwest Ohio. Model developed by combining each individual species model from Maxent. Zero indicates no species likely present to a high of all seven species likely present.

continued and we hope to expand it to not only other parks, but urban and suburban areas throughout the region.

Habitat models provide a powerful tool for monitoring and conserving vulnerable species in a rapidly changing world. Our models are a baseline, or a first step, in characterizing the diversity patterns in the area and modeling presence on a macrohabitat scale, something that has not been done for bats. These models can be refined and test data can be included into training data as new test data becomes available. We used variables that are easily extracted from GIS and updated over time. The models allow us to aid managers in finding potentially important foraging sites and assist in long-term monitoring.

Indeed, these models have already been used to identify areas of priority conservation within the protected areas (Lipps, unpublished data). We hope that they can be used to identify areas outside of parks that could be protected as commuting or foraging habitat. With this long term monitoring, there is also the potential to understand how changes such as management may increase (for example by removing structural clutter (Tichenell et al., 2011), or decrease (through loss of canopy cover (Smith and Gehrt, 2010) species presence.

The results of our models indicate a need to maintain heterogeneity in habitat types. It appears that protected areas within the Oak Openings Region can support a suite of species when considering foraging activity as long as a variety of successional states are maintained. At this macrohabitat scale, and within protected areas, the fragmentation and development that we measured did not appear to affect the presence of these species, although very few areas outside of the parks appear to be suitable habitat.

Distance to roads had a negligible contribution to all species models; the largest contribution of this factor was for little brown bats. This species is generally found further away from urban development (Duchamp and Swihart, 2008), but roads could serve as commuting areas to roosts (Riskin and Pybus, 1998); insect hot spots due to heat retention; openings within forests; or edges in areas where tree lines are next to roads. The concentration of suitable habitat in the northern part of the Oak Openings Region follows the drainage ditches that are unique to this area, which are also associated with roads.

Measures of forest cover were predictors for the taxa generally considered to be forest obligate (northern *Myotis* and little brown bats), while the presence of open areas -prairie and savanna- contributed to the models of the larger bodied eastern red bats. The presence of savanna also contributed to little brown, tri-colored, evening and silver-haired bats, indicating a need to explore the importance of this habitat type further.

Bats are an integral part of North American ecosystems as the primary predators of night flying insects, and as such, it is important that we understand how to maintain populations of these organisms across diverse contexts. This is an important consideration within protected areas as they are often considered islands of suitable habitat. Through this work, we found that the scale of consideration is important and may differ across species, but that the macrohabitat scale is generally predictive of species presence and can be used in predicting species occurrence within protected areas of this region. In terms of management, heterogeneity of land cover and successional states is important in supporting a diverse group of species. Using the combined approach of Maxent modeling and model testing using data collected by citizen scientists, we were able to increase our understanding of the important habitat components for bat species in protected areas to assist in conservation and management, while engaging and educating the local stakeholders.

ACKNOWLEDGEMENTS

This research was part of a PhD dissertation work of J. Sewald and was partially supported by National Science Foundation (DEB-1110481), Bowling Green State University, Bat Conservation International, The Ohio Division of Wildlife through the State Wildlife Grants Program, and the Toledo Naturalists Association. We would like to thank H. Michaels and M. van Staaden for assistance with this project, and K. Francl, C. Corben and K. Livengood for assistance and use of call libraries. The project would not have been possible without the help of E. Tucker, B. Crim, K. Kuhn, M. Vogel, K. Schultes, T. Schetter, M. Cross, and K. Baczynski. We are also grateful to the Metroparks of the Toledo area and Karen Menard as well as the numerous and dedicated citizen science volunteers.

REFERENCES

Abella SR, Jaeger JF, Gehring DH, Jacksy RG, MenardKS, High K (2001). Restoring historic plant communities in the Oak Opening Region of Northwest Ohio. Ecol. Rest. 19:155-160.

Aldridge H, Rautenbach IL (1987). Morphology, echolocation and resource partitioning in insectivorous bats. J. Anim. Ecol.56:763-788.

Anderson RP (2003). Real vs. artefactual absences in species distributions: tests for Oryzomysalbigularis (Rodentia:Muridae) in Venezuela. J. Biogeog. 30:591-605.

Avila-Flores R, Fenton MB (2005). Use of spatial features by foraging insectivorous bats in a large urban landscape. J. Mammal. 86:1193-1204

Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, ShirkJ (2009). Citizen science: A developing tool for expanding scientific knowledge and scientific literacy. BioSci. 59:977-984.

Brewer LG,Vankat JL(2004). Description of vegetation of the Oak Opening of Northwestern Ohio at the time of Euro-American settlement.Ohio. J. Sci. 104:76-85.

Brigham RM (2007). Bats in forests: what we know and what we need to learn. In Bats in Forest:Conservation and Management. in Lacki MJ, Hayes JP, Kurta A., editors. The John Hopkins University Press, Baltimore. pp. 1-16.
Britzke ER, Murray KL, Heywood JS, Robbins LW (2002). Acoustic identification. In: A. Kurta, and J Kennedy, editors. The Indiana bat:Biology and management. Bat Conservation International, Inc., Austin, TX. pp. 221-227.
Brooks RT (2009). Habitat-associated and temporal patterns of bat activity in a diverse forest landscape of southern New England, USA. Biol. Conserv. 18:529-545.
Brooks RT, Ford WM (2005). Bat activity in a forest landscape of central Massachusetts. Northeast. Nat. 12:447-467.
Cochran ES, Lawrence JF, Christensen C, Jakka RS (2009).The quake-catcher network: citizen science expanding seismic horizons. Seismol. Res. Lett.80:26-30.
Dixon MD (2011). Relationship between land cover and insectivorous bat activity in an urban landscape. Urban Ecosys.10.1007/s11252-011-0219-y.
Donnelly R, Marzluff JM (2004). Importance of reserve size and landscape context to urban bird conservation. Conserv. Biol.18:733-745.
Duchamp JE, Sparks DW, Whitaker Jr. JO (2004). Foraging-habitat selection by bats at an urban-rural interface:comparison between a successful and a less successful species. Can. J. Zool. 82:1157-1164.
Duchamp JE, Swihart RK (2008). Shifts in bat community structure related to evolved traits and features of human-altered landscapes. Landscape Ecol. 23:849-860.
Elith J, Graham CH, Anderson RP, Dudik M, Ferrier S, Guisan A, Hijmans RJ, Huettmann F, Leathwick JR, Lehmann A, Lohmann LG, Loiselle BA, Manion G, Moritz C, Nakamura M, Nakazawa Y, Overton JM, Peterson AT, Phillips SJ, Richardson K, Scachetti-Pereira R, Schapire RE, Soberon J, Williams S, Wisz MS, Zimmermann NE (2006). Novel methods improve prediction of species' distributions from occurrence data. Ecography 29:129-151.
Erickson JL, West S (2003). Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington. Biol. Conserv. 109:95-102.
Estes WA, Mannan W(2003). Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington. Biol. Conserv. 109:107-116.
Ewert DN, Soulliere RD, Macleod RD, Shieldcastle MC, Rodewald PG, Fujimura E, Shieldcastle J, Gates RJ (2005). Migratory bird stopover site attributes in the western Lake Erie basin. Final report to The George Gund Foundation.
Fawcett T (2006). An introduction to ROC analysis. Pattern Recognit. Lett. 27:861-874.
Ford WM, Menzel JM, Menzel MA, Edwards JW, Kilgo JC (2006). Presence and absence of bats across habitat scales in the upper coastal plain of South Carolina. J. Wildl. Manage. 70:1200-1209.
Ford WM, Menzel MA, Rodrigue JL, Menzel JM, Johnson JB (2005). Relating bat species presence to simple habitat measures in a central Appalachian forest. Biol. Conserv. 126:528-539.
Francl K (2008). Summer bat activity at the woodland seasonal pools in the Northern Great Lakes Region. Wetlands 28:117-124.
Francl, K, W.M. Ford, Castleberry SB (2004). Bat activity in Central Appalachian Wetlands. Ga. J. Sci. 62:87-94.
Gehrt SD, Chelsvig JE (2003). Bat activity in an urban landscape:patterns at the landscape and microhabitat scale. Ecol. Appl. 13:939-950.
Gehrt SD, Chelsvig JE(2004). Species-specific patterns of bat activity in an urban landscape. Ecol. Appl. 14:625-635.
Glendell M,Vaughan N(2002). Foraging activity of bats in historic landscape parks in relation to habitat composition and park management. Anim. Conserv. 5:309-316.
Grindal SD, Morissette JL, Brigham RM(1999). Concentration of bat activity in riparian habitats over an elevation gradient. Can. J. Zool. 77:972-977.
Guisan A, Zimmerman NE (2000). Predictive habitat distribution models in ecology. Ecol. Modell. 135:147-186.
Hayes JP (1997). Temporal variation in activity of bats and the design of echolocation-monitoring studies. J. Mammal. 78:514-520.
Hernandez PA, Graham CH, Master LL, Albert DL (2006). The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography 29:773-785.
Hughes AC, Satasook C, Bates PJ Bumrungsri S, Jones G (2012). The projected effects of climate and vegetation changes on the distribution and diversity of Southeast Asian bats. Glob. Chang. Biol. 18:1854-1865.
Johnson JB, Gates JE (2008). Bats of Assateague Island National Seashore, Maryland. Am. Midl. Nat. 160:160-170.
Johnson JB, Gates JE, Ford WM (2008). Distribution and activity of bats at local and landscape scales within a rural-urban gradient. Urban Ecosys. 11:227-242.
Jung K,Kalko EKV(2011). Adaptability and vulnerability of high flying neotropical aerial insectivorous bats to urbanization. Biodivers. Res. 17:262-274.
Kumar S, Stohlgren TJ (2009). Maxent modeling for predicting suitable habitat for threatened and endangered tree Canacomyricamonticolain New Caledonia. J. Ecol. Nat. Environ. 1:94-98.
Kurta A, Teramino JA (1992). Bat community structure in an urban park. Ecography 15:257-261.
Kurta A, Whitaker Jr. JO (1998). Diet of the endangered Indiana bat (*Myotissodalis*) on the northern edge of its range. Am. Midl. Nat. 140:280-286.
Lacki MJ, Amelon SK, Baker MD (2007). Foraging ecology of bats in forests. In: Lacki MJ, Hayes JP, and Kurta A, editors. Bats in Forests: Conservation and management. The John Hopkins University Press, Baltimore. pp. 83-128.
Lamb JM, Ralph TMC, Goodman SM, Bogdanowicz W, Fahr J, Gajewska M, Eger JP, Benda JP, Taylor PJ (2008). Phylogeography and predicted distribution of African-Arabian and Malagasy populations of giant mastiff bats, Otomops spp. (Chiroptera: Molossidae). Acta Chiropterologica 10:21-40.
Lee T, Quinn MS, Duke D(2006). Citizen, science, highways, and wildlife: Using a web-based GIS to engage citizens in collecting wildlife information. Ecol. Soc. 11:www.ecologyandsociety.org/vol11/iss1/art11/
Lepczyk CA (2005). Integrating published data and citizen science to describe bird diversity across a landscape. J. Appl. Ecol. 42:672-677.
Livengood K (2003). The anabat detector's zone of reception and the factors that affect detection volume. University of Missouri-Columbia, Columbia. p. 134.
Loeb SC, O'Keefe JM(2006). Habitat use by forest bats in South Carolina in relation to local, stand, and landscape characteristic. J. Wildl. Manage. 70:1210-1218.
Loeb SC, Post CJ, Jall ST(2009). Relationship between urbanization and bat community stucture in national parks of the southeastern U.S. Urban Ecosyst. 12:197-214.
McGarigal K, Marks BJ (1995). FRAGSTATS:spatial pattern analysis program for quantifying landscape structure. USDA Forest Service General Technical Report PNWGTR–351, USDA Forest Service, Pacific Northwest Research Station, Portland,Oregon. p.134.
Noss RF, LaRoe ET, Scott JM (2005). Endangered ecosystems of the United States: a preliminary assessment of loss and degradation., Biol. Rep. 28. ed. N.B.S. U.S. Department of the Interior. http://biology.usgs.gov/pubs/ecosys.htm
Pearson RG, Raxworthy CJ, Nakamura M, Peterson AT (2007). Predicting speciesdistributions from small numbers of occurrence records:a test case using cryptic geckos in Madagascar. J. Biogeog. 34:102-117.
Phillips SJ, Anderson RP, Schapire RE (2006). Maximum entropy modeling of speciesgeographic distributions. Ecol. Model. 190:231-259.
Phillips SJ, Dudik M (2008). Modeling of species distributions with Maxent: newextensions and a comprehensive evaluation. Ecography 31:167-175.
Raddick MJ, Bracey G, Gay PL, Lintott CJ, Murray P, Schawinski K,

Szalay AS, Vandenberg J (2010). Galaxy Zoo: Exploring the motivations of citizen science volunteers. Astron. Educ. Rev. 9: 010103-1, 10.3847/AER2009036

Ratcliffe JM, Dawson JW (2003). Behavioural flexibility: the little brown bat, Mytois lucifugus, and the northern long-eared bat, M. septentrionalis, both glean and hawk prey. Anim. Behav. 66:847-856.

Rebelo H, Tarroso P, Jones G (2010). Predicted impact of climate change on European bats in relation to their biogeographic patterns. Glob. Chang. Biol. 16:561-576.

Riesch H, Potter C (2013). Citizen science as seen by scientists:Methodological, epistemological and ethical dimensions. Public Understanding of Science (2013):0963662513497324

Riskin DK, Pybus MJ(1998). The use of exposed diurnal roosts in Alberta by the little brown bat, Myotislucifugus. Can. J. Zool. 76:767-772.

Rothley KD, Berger CN, Gonzales C, Webster EM, Rubenstein DI (2004). Combining strategies to select reserves in fragmented landscapes. Conserv. Biol. 18:1121-1131.

Saab V (1999). Importance of spatial scale to habitat use by breeding birds in riparian forests:A hierarchical analysis. Ecol. Appl. 9:135-151.

Schetter TA (2012). A multiscale spatial analysis of oak openings plant diversity with implications for conservation and management. Bowling Green State University, Bowling Green, OH.

Schetter TA, Root KV (2011). Assessing an imperiled oak savanna landscape in northwestern Ohio using Landsat data. Nat. Areas J. 31:181-130.

Smith, DA, Gehrt SD (2010). Bat response to woodland restoration within urban forest fragments. Restor. Ecol. 18:914-923.

Sparks DW, Ritzi CM, Duchamp JE, Whitaker Jr. JO (2005).Foraging habitat of the Indiana bat (Myotissodalis) at an urban-rural interface. J. Mammal. 86:713-718.

Swets J (1988). Measuring the accuracy of diagnostic systems. Sci. 240:1285-1293.

Tichenell MA, Williams RA, Ghert SD (2011). Bat response to shelterwoodharvests and forest structure in oak-hickory forests. For. Ecol. Manage. 262:980-988.

U.S. Census Bureau (2009). Technical documentation: TIGER/Line Shapefiles. U.S. Census Bureau, Washington D.C.

Vindigni MA, Morris AD, Miller DA (2009).Use of modified water sources by bats in a managed pine landscape. For. Ecol. Manage. 258:2056-2061.

Walsh AL, Hutson TM, Harris S (1993). UK volunteer bat groups and the British bat and habitats survey, in: K. Kapteyn, editor. Proceedings of the first European bat detector workshop. Netherlands Bat Research Foundation, Amsterdam. pp. 113-123.

Yates MD, Muzika RM (2006). Effect of forest structure and fragmentation on site occupancy of bat species in Missouri Ozark forests. J. Wildl. Manage. 70:1238-1248.

Zimmerman GS, Glanz WE(2000). Habitat use by bats in eastern Maine. J. Wildl. Manage. 64:1032-104.

academicJournals

Vol. 6(2), pp. 184-193, February 2014
DOI: 10.5897/IJBC2013.0662
ISSN 2141-243X © 2014 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Morphological characterization of shea tree (*Vitellaria paradoxa* subsp. *paradoxa*) populations in the region of Mandoul in Chad

Christophe DJEKOTA[1], Diaga DIOUF[2]*, Seyni SANE[3], Mame Samba MBAYE[3] and Kandioura NOBA[3]

[1]Faculté des Sciences Exactes et Appliquées. Département de Biologie, Université de N'Djaména, B.P 1027, Tchad.
[2]Laboratoire de Biotechnologies Végétales, Département de Biologie Végétale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, BP 5005 Dakar-Fann, Dakar, Sénégal.
[3]Laboratoire de Botanique et Biodiversité, Département de Biologie Végétale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, BP 5005 Dakar-Fann, Dakar, Sénégal.

Accepted 6 January, 2014

Quantitative characteristics of leaf, fruit and nut collected from *Vitellaria paradoxa* subsp. *paradoxa* growing in Kol, Kemkian and Matekaga located in the region of Mandoul of Southern Chad were analyzed. Our results reveal variation of the measured morphological parameters. The smallest lamina length (15.5 cm) was found in Kol and the longest (26.3 cm) in Matekaga. The biggest lamina width (5.4 cm) and nut length (3.8 cm) were found in Kol. Using the correlation matrix data, our investigations revealed that lamina length and peduncle length were correlated with 92%. Fruit width was correlated with peduncle length and fruit length with 52 and 83%, respectively. Nut length was correlated with peduncle length, fruit length and fruit width with 55, 78 and 77%, respectively. In contrast, nut length was correlated with fruit length, fruit width and nut length with 68, 78 and 87%, respectively. The dendrograms analyses revealed the existence of four groups within and between sites instead of the six ethno-varieties described by folk classification. These findings raise the need to use molecular markers to unravel the underlying variation for use in selection and genetic improvement of shea tree.

Key words: *Vitellaria paradoxa*, shea butter tree, morphological characters, folk classification, ethno-varieties, Chad.

INTRODUCTION

The semi-domesticated shea butter tree (*Vitellaria paradoxa* (C.F. Gaertner) syn. *Butyrospermum parkii* (Kotschy), *Butyrospermum paradoxum* (C.F. Gaertner) Hepper, Family Sapotaceae) is wildly distributed in the Sudano-Sahalian region from Senegal to Uganda (Hall et al., 1996; Hemsley, 1968; Salle et al., 1991). Presently two subspecies have been identified. *V. paradoxa* subsp. *paradoxa* is found in West and Central Africa (Hall et al*.,* 1996; Salle et al., 1991; Sanou et al*.,* 2005; Fontaine et al*.,* 2004; Allal et al*.,* 2008; Nyarko et al*.,* 2012; Kelly et al*.,* 2004), while *V. paradoxa* subsp. *nilotica* is common in East Africa (Soudan, Ethiopia, Uganda and Republic Demotratic of Congo) (Gwali et al., 2012; Okullo et al*.,* 2004; Byakagaba et al*.,* 2011; Okiror et al*.,* 2012). The tree shape is influenced by various environmental factors and they are well identified by farmers according to the folk classification. During the wet season, the tree produces fruits edible by both human and animals. The fruits contain 1 to 3 large solitary seeds, rich in fat and oil used in a variety of purposes such as cooking (Abbiw, 1990),

*Corresponding author. E-mail: diaga.diouf@ucad.edu.sn.

medicinal, hair and skin ointments and as a base for industrial manufacture of confectioneries (Cidell and Alberts, 2006). The oil is also used in traditional and social rituals such as marriages, funerals, coronations and rainmaking (Ferris et al., 2004; Gwali et al., 2012; Hall et al., 1996; Moore, 2008). The wood of the shea butter tree is used for charcoal, furniture and construction, and the latex for glue making (Lovett and Haq, 2000a). In addition, the trees are used in agroforestry systems that play an important role in the adaptation to climate change such as contribution to soil fertility (Rao et al., 2007). For these reasons, shea butter tree generates significant incomes for households.

Because of its economic importance, genotype studies were performed based on morphological characters leading to the identification of several phenotypes including the domesticated *V. paradoxa* (Chevalier, 1943, 1948; Nafan et al., 2007; Ruyssen, 1957; Sanou et al., 2005, 2006; Ugese et al., 2010). In 1943, Chevalier identified eight varieties based on fruit and leaf variation (*cuneata*, *ferruginea*, *floccosa*, *mangifolia*, *nilotica*, *parvifolia*, *poissoni* and *serotina*). In 1957, the taxonomy was revisited by Ruyssen using tree shapes and sizes, fruits, nuts and leaves leading to the description of *V. mangifolium* as a subspecies containing two varieties (*viridis* and *rubifolia*). Further, using fruit morphology, nut color, crown shape and habitat types, phenotype variation was noticed for the shea tree in Cameroon (Nafan et al., 2007; Lamien et al., 2007). This variation was in agreement with the folk classification distinguishing ethno-varieties which was used by West African farmers to select and preserve shea tree (Gwali et al., 2011; Lovett and Haq, 2000b). Gwali et al. (2012) used morphological characters of 176 trees representing 44 ethno-varieties in Uganda to establish the congruence between the morphological variation and folk classification. Their results showed a good congruence with folk classification when they combined the qualitative traits as perceived by farmers. Recently, Mbaiguinam et al. (2007) performed studies in the population of shea tree from Mandoul region using chemical characteristics and concluded that there was no significant difference of fatty acids content within varieties. In addition, they reported that the shea butter profile was between those from Cameroon and Uganda. Nevertheless, substantial darkness points have to be addressed particularly in Chad where the level of the morphological diversity of the tree is still understood.

The objectives of this study were to discriminate the morphotypes of the shea trees growing in the region of Mandoul located in Southern Chad using leaf, fruit and nut characteristics.

MATERIALS AND METHODS

Study area and experimental design

The present study was conducted in three sites (Matekaga, Kemkian and Kol*)* located in the region of Mandoul in southern Chad, where the mean annual precipitation was 1,200 mm (Figure 1a, b). The rainy season lasts from May to October with mean temperatures of 22°C. The dry season lasts from November to April with average temperature of 32°C. In the area of our experiment, the soil was sandy, lateritic or ferralitic. Each site was swept by 4 or 8 transects crossing in its center using a GPS (Garmin, city and country). Along each transect, the quadrants were separated by 100 m. These sites were chosen because of the high density of their shea tree. It should be noted that Kemkian means the village of shea tree in the local language.

Plant material

Two hundred and forty (240) shea trees distributed in six ethno-varieties according to folk classification were investigated. The folk classification of the accessions was consistent because in the area where the materials were collected, people spoke the same language. The sampling method consisted of selecting 104 trees in Matekaga, 64 in Kemkian and 72 in Kol.

Data collection

Ten adult fresh leafy twigs and mature fruits without parasites were collected randomly from each tree. The length and the width of the leaves were measured using a vernier caliper (Shanghai, China). The total length of the leaf consisted of the length of petiole and that of lamina. The length and the width of fruit and the diameter of the nuts collected from fruits were measured for each accession (Figure 2). For accurate measurement, a mean value was calculated from ten organs. In addition, the mean value of length and width of each organ within site were calculated. The mature fruits were collected in May and September 2007. These data were used as raw material, subjected to principal component analysis (PCA) and analysis of molecular variance (AMOVA).

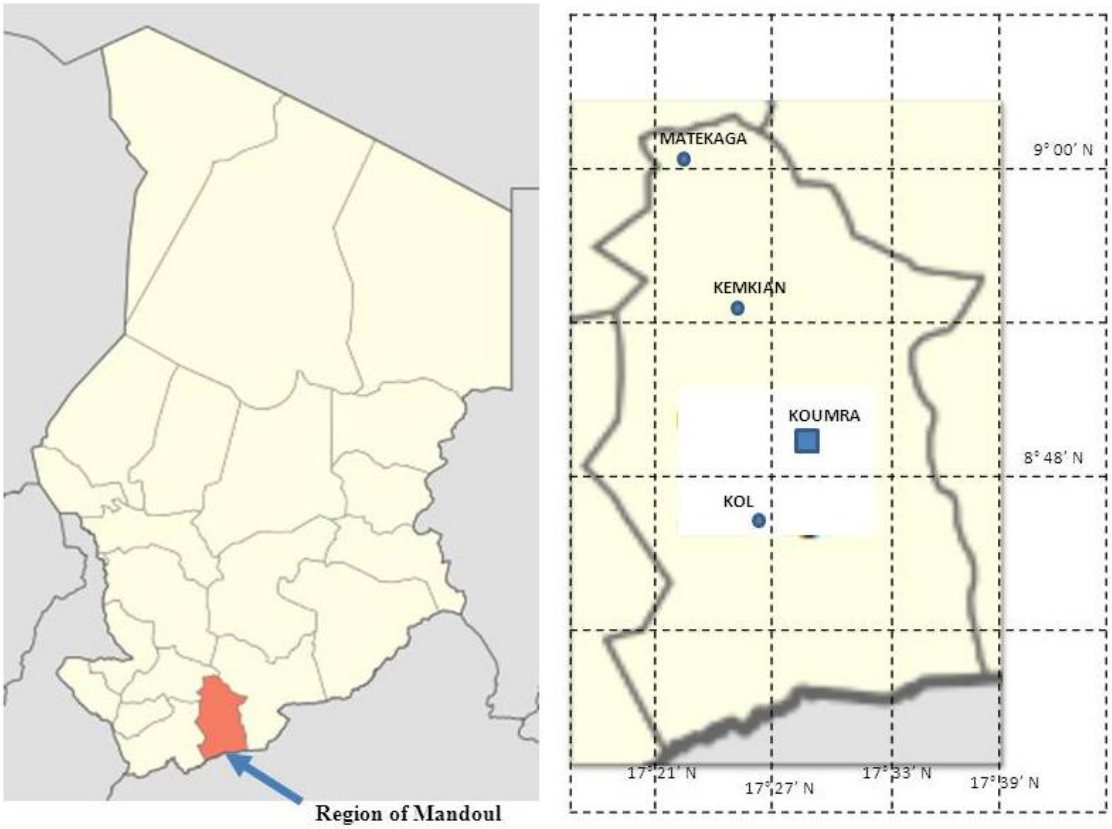
Multivariate analysis

PCA was performed using statistical package ADE-4 coupled with a hierarchical cluster ascendant (HCA) to group the accessions based on their similarities. Leaves, fruits and nuts were considered as variable but the 240 accessions were projected in a plane including the two first axes. To perform an ascending hierarchical clustering of the accessions, the coordinates of the individuals on the factorial axes as similarity matrix, the squared Euclidean distance and the Ward's method were used. The dendrogram was generated using the R (version R-2.9.0, ADE4 package) software (R Development Core Team, 2011).

RESULTS

Morphological character analyses

The mean values of leaf, fruit and nut parameters of the samples collected from each site allowed to estimate their variation. The parameters measured from the leaves showed that the lamina length ranged from 15.8 to 23.6 cm for the trees growing in Kemkian, 15.5 to 24.2 cm in Kol, 16.5 to 26.3 cm in Matekaga. The percentage of leaves for which the length was more than 20 cm was 81% in Kemkian, 76% in Kol and 69% in Matekaga. The width of the lamina ranged from 3.2 to 5 cm in Matekaga,



a. Map of Chad b. Map of Mandoul's region

Figure 1. Map of Chad and region of Mandoul showing the localization of the sites where the samples were collected (Ministery of Interior, 2009).

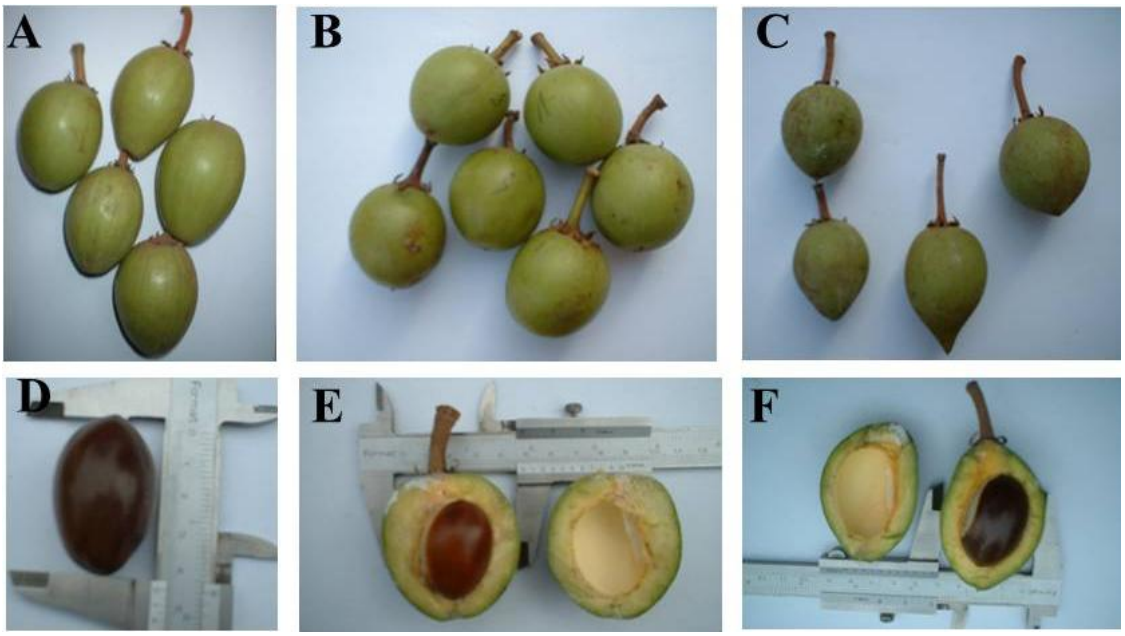


Figure 2. Morphological characteristics of fruits and nuts. (A) Ovoid fruit; (B) Spherical fruit; (C) Elliptical fruit; (D) Ovoid nut; (E) Spherical fruit; (F) Elliptical fruit.

Table 1. Correlations between morphological characters.

	PET	LL	LW	PL	FL	FW	NL
LL	0.92*						
LW	0.18	0.46					
PL	0.00	-0.02	-0.11				
FL	0.05	0.05	-0.06	0.48			
FW	0.03	0.00	-0.10	0.52*	0.83*		
NL	0.06	0.02	-0.12	0.55*	0.78*	0.77*	
NW	0.01	-0.01	-0.07	0.42	0.68*	0.78*	0.87*

PET, Petiole length; LL, lamina length; LW, lamina width; PL, peduncle length; FL, fruit length; FW, Fruit width; NL, Nut length; NW, Nut width. *The significant values are in bold.

3 to 5 cm in Kemkian, 3 to 5.4 cm in Kol. The length of the petiole ranged from 5.8 to 11.9 cm for the leaves collected in Matekaga, from 5.7 to 11.2 cm in Kemkian and 5.7 to 10.2 cm in Kol.

Fruit peduncle length variability was also reported in this study. It ranged from 1 to 3.1 cm in Kol, 1 to 3.3 cm in Kemkian and 1 to 2.7 cm in Matekaga. The fruit length varied from 2.5 to 5.5 cm in Matekaga, 2.6 to 5 cm in Kemkian and from 2.6 to 5.5 cm in Kol. Assessing the fruit width, our study founded that it varied from 2.3 to 4.3 cm in Matekaga, 2.4 to 4.4 cm in Kemkian and 2.4 to 4.3 cm in Kol. The nut length varied from 1.9 to 3.6 cm in Matekaga, 1.9 to 3.3 cm in Kemkian and 1.9 to 3.8 cm in Kol. Finally, the measure performed on the nut width showed that their values ranged from 1.5 to 2.8 cm in Matekaga, 1.4 to 2.4 cm in Kemkian and 1.5 to 2.6 cm in Kol.

Statistical analysis of morphological data

PCA showed that the two principal axes explained 72.95% of the variance observed. The first axis expressed 46.54% of the total variance (data not shown). The variables, nut length, fruit width, nut width and fruit length, contributed to 86.96, 83.59, 78.53 and 77.97%, respectively. The second axis expressed 26.41% of the total variance. The lamina length and petiole length represented 97.4 and 82.87% of the variance, respectively. The third axis explained 10.66% of the total variance where lamina width explained 65.71% of this value. Finally, the fourth axis expressed 8.11% of the variance where the peduncle length explained 54.84% of this value and is associated with the nut width which contributed to 5.34% of the variance.

The correlation matrix showed that lamina length and petiole length were correlated with 92%. Fruit width was correlated with peduncle length and fruit length with 52 and 83%, respectively. Nut length was correlated with peduncle length, fruit length and fruit width with 55, 78 and 77%, respectively. In contrast, nut width was correlated with fruit length, fruit width and nut length with 68, 78 and 87%, respectively (Table 1). In addition, there was significant variation of the mean of the peduncle length between the samples collected in Matekaga, Kemkian and Kol. The mean of the fruit length was similar between Kol and Matekaga but it was significantly different with the ones found in Kol (Figure 3A). Figure 3B showed that nut characteristics (means of length and width) were not different between Matekaga and Kol. These characterristics were significantly different with the ones collected on the nuts from Kol. No significant difference was observed between the mean of the peduncle length in Matekaga, Kemkian and Kol. Similar results were observed for the means of the lamina length and lamina width taken individually (Figure 3C).

Morphological variation within sites

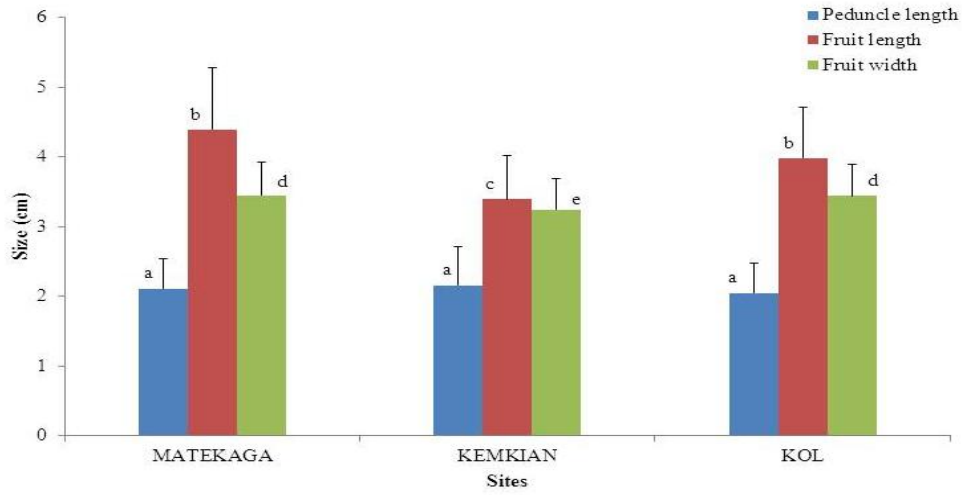
Dendrograms performed using leaf, fruit or nut parameters separately or in pair combinations failed to discriminate accurately the samples collected from each site (data not shown). In contrast, a combination of leaf, fruit and nut parameters allowed a good resolution between individual samples within each site. In Figure 4A, samples collected in Kemkian were divided into four main groups. In the group I, two sub-groups were observed. The first sub-group encompassed A121 and A141 which were clustering together while A110 and A162 were sister of A163. In the same sub-group, A120 and A142 were clustering together as A109 and A130 did. The genetic relationship among the individuals forming the second sub-group is also well resolved. The group II was also sub-divided into two sub-groups which are well resolved. In group III, the clustering was very clear except for A139 and A160 which erre linked with a short branch. The group IV was sub-divided into several numbers of sub-groups.

The material collected in Kol was divided into four groups (Figure 4B). The first group showed a high coefficient of similarity among accessions and two main sub-groups as the second group did. The third group encompassed two main sub-groups including several subdivisions each, while the fourth group was also well structured.

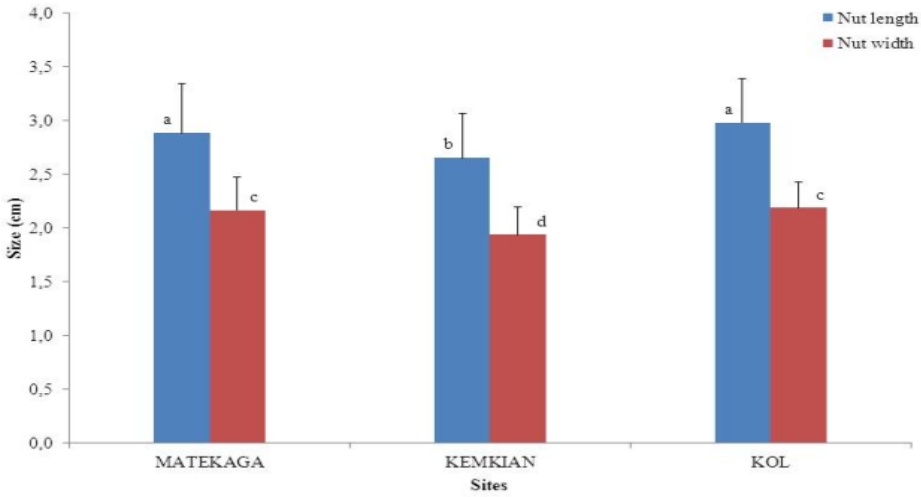
In Matekaga, based on the dendrogram, the biological material was divided into four groups (Figure 4C). The first group was divided in two main sub-groups which were well resolved. The second group encompassed several sub-groups as the third but the fourth was more diversified.

Trait variation between sites

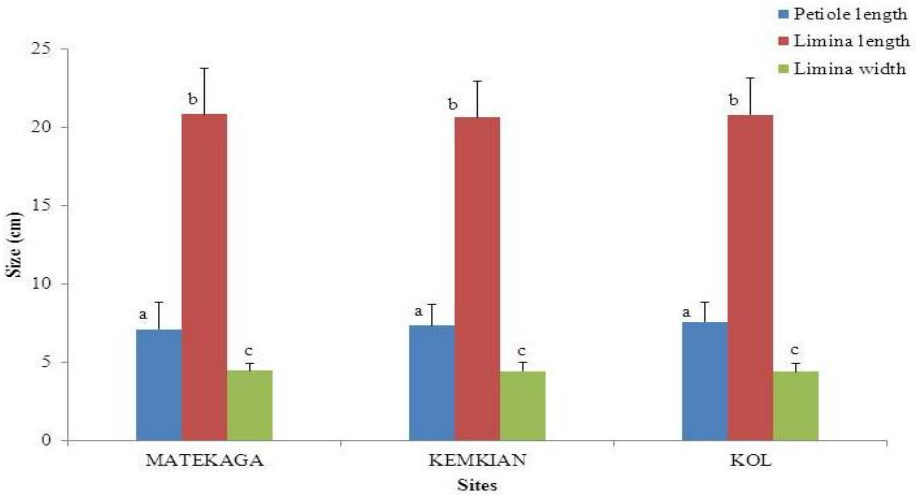
The dendrogram in Figure 5 contained the 240 individuals growing in the three sites (Kemkian, Kol and



A: Peduncle and fruit characters variation between sites.

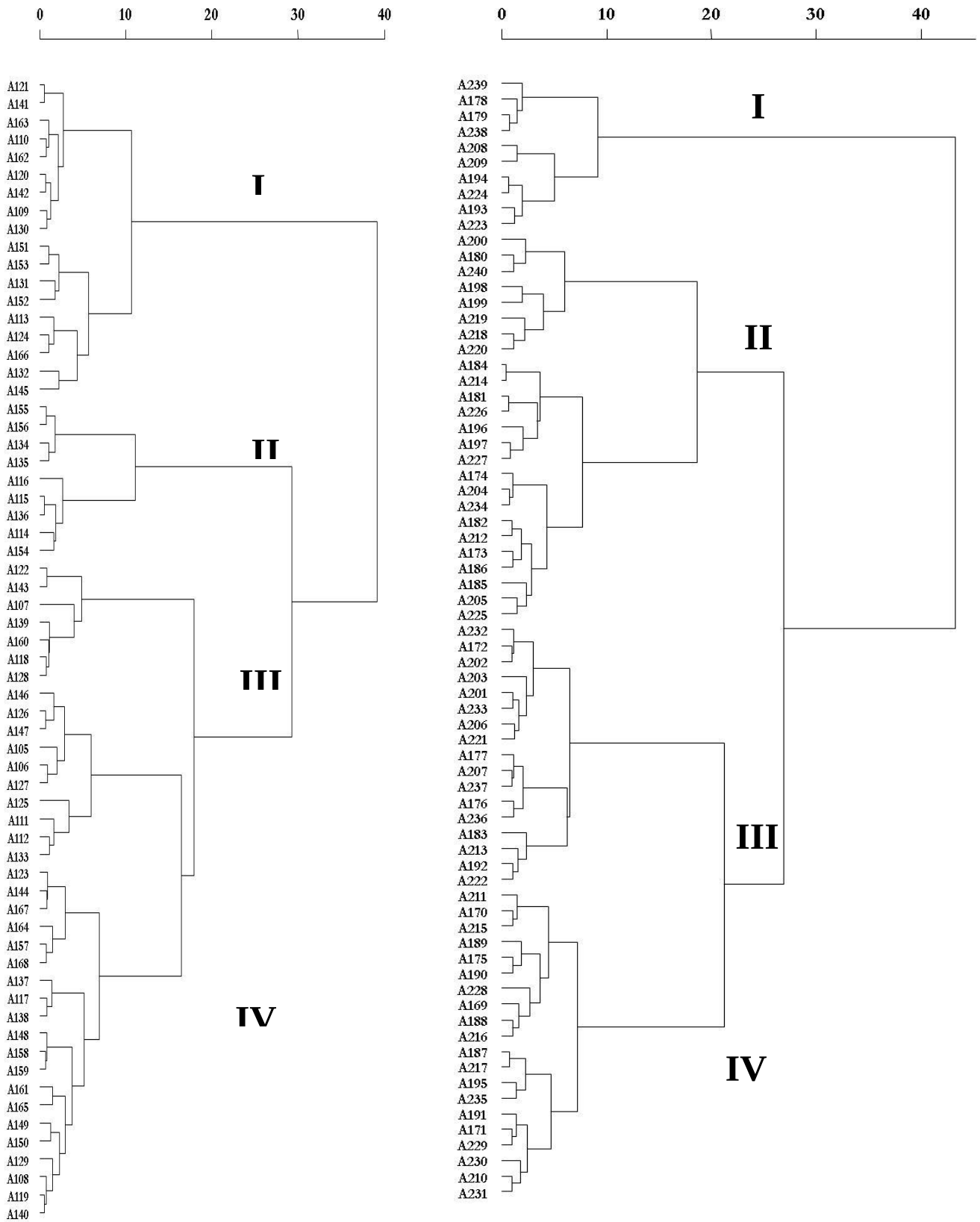


B: Nut characters variation between sites.



C: Leave characters variation between sites.

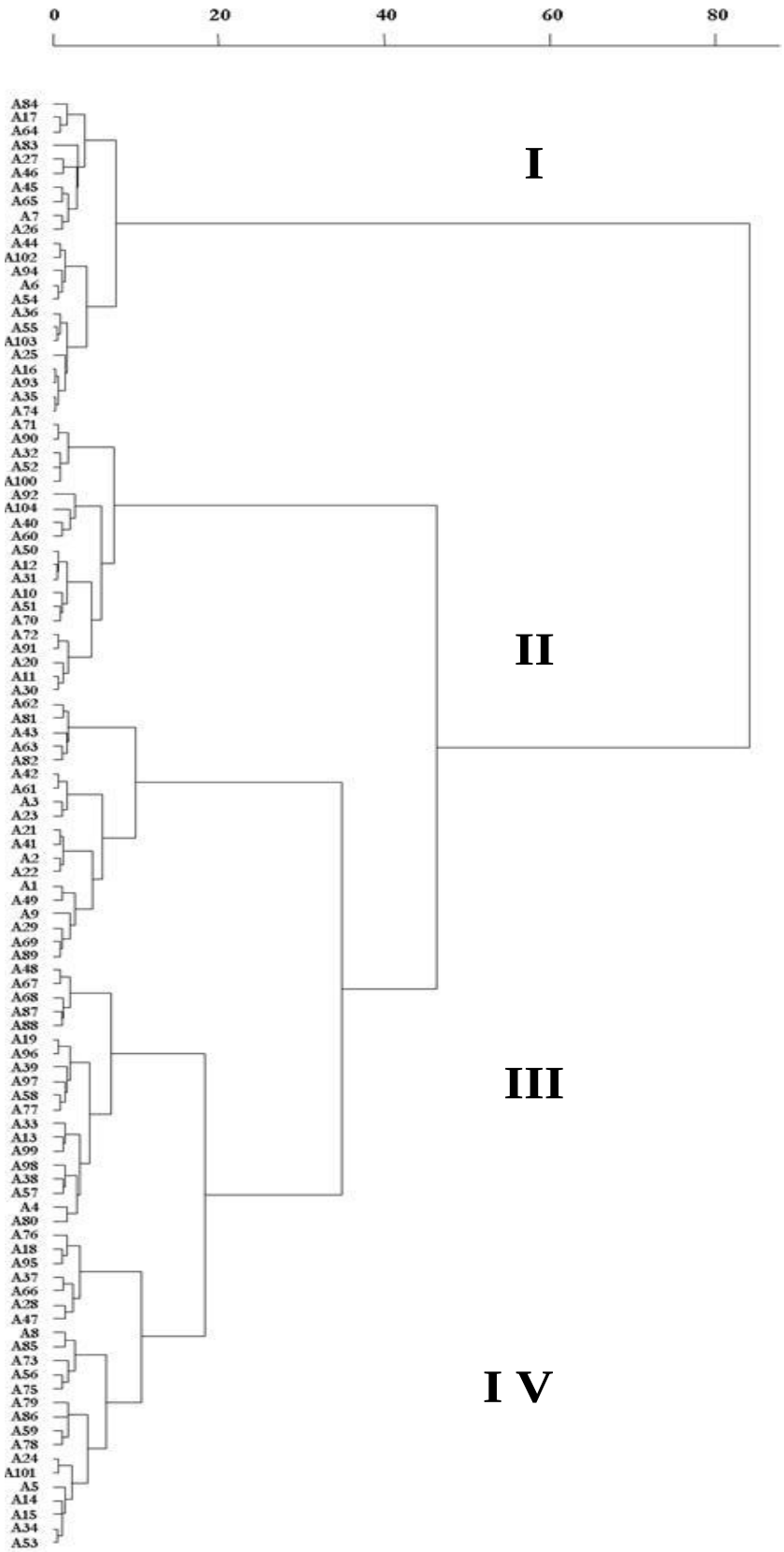
Figure 3. Variation of morphological characters of shea butter tree between sites. The characters affacted by the same letter are not statistically differents.



A: Dendrogam showing dissimilarities between Individual shea tree in Kemkian

B: Dendrogam showing dissimilarities between individual shea tree in Kol

Figure 4. Dendrograms showing dissimilarities within sites



C: Dendrogam showing dissimilarities between individual shea tree in Matekaga

Figure 4. Contd.

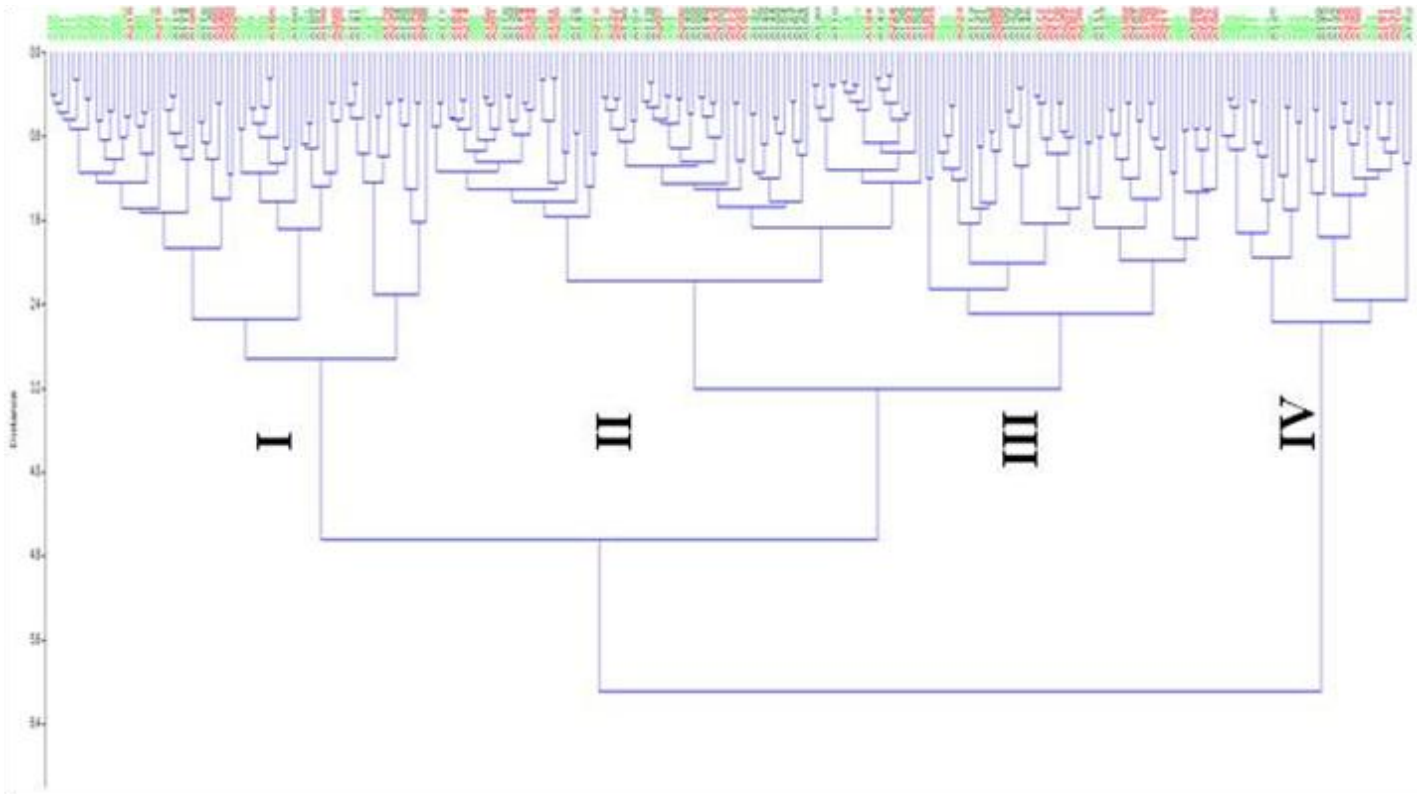


Figure 5. Dendrogam showing dissimilarities between individual shea tree among different sites (Kemkian, Kol and Matekaga)

Matekaga) and showed four groups. Group I included 36.5% of individuals from Matakaga and was divided into four sub-groups. The first sub-group included 18 (17.3%) individuals from Matekaga and only 2 from Kol. A100 from Matekaga was clustered with A218 from Kol. In the third sub-group, the majority of the individuals were from Kol while the fourth sub-group includes most of the individuals from Matekaga. The cluster A98 from Matekaga and A185 from Kemkian, A121/A141 from Kemkian and A134/A135 from Kemkian showed low dissimilarity. The group II included 69% of the individuals from Kol which were distributed in several sub-groups. The clusters formed by A39 from Matekaga /A182 from Kol, A19/A96 from Matekaga and A181/A226 from Kol showed low dissimilarity. The group III included 26 individuals (36.1%) from Kol, 11 (10.5%) from Matekaga and 12 (17.8%) from Kemkian. Most of the samples were gathered by site except the clusters A153 from Kemkian and A208 from Kol and A5 from Matekaga and A177 from Kol. The sample A107 from Kemkian which were grouped with A189 from Kol were nested inside the Kol provenances. The group IV encompassed 34 individuals among which, 20 were from Matekaga, 6 from Kemkian and 8 from Kol. A81 from Matekaga and A105 from Kemkian were grouped together, as A83 from Matekaga and A152 from Kemkian and A43 from Matekaga and A191 from Kol.

DISCUSSION

Understanding population genetic structure is relevant to phytogenetic resources management because it is the first step before implementing any selection process. Phytogenetic resources management was applied to a wide range of economically important plants including shea tree. In its area of distribution particularly in West Africa, shea tree resource management has been mainly based on folk classification for centuries aiming at conservation, domestication and selection of superior individuals (Lovett and Haq, 2000b). On the other hand, in Chad, few studies were reported aiming to enhance our understanding of shea tree genetic variation (Mbaiguinam et al., 2007).

Morphological variations of the shea tree

In this study, a variation in lamina length was observed within and between sites. The smallest lamina length (15.5 cm) was found in Kol, while the longest (26.3 cm) in Matekaga. In addition, the biggest lamina width was found in Kol with 5.4 cm. This morphological variation suggested that a single morphotype was not growing in these areas. Variation of the length of petiole was also observed within site and between sites. The longest petiole

was reported in the population from Matekaga while the smallest was observed in Kol. These findings are agreement with the results of Nyarko et al. (2012) who reported petiole length variation in shea tree from Ghana. In the same manner, as the variation of the peduncle length within sites and between sites, the longest peduncle length (3.3 cm) was observed in Kemkian while the longest fruit was found in Matekaga and Kol. The morphological parameters collected from fruits and nuts showed variation within sites but significant differences were not observed between sites. The variations of the parameters from Chad observed in this study were close to those estimated from shea trees in Mali, Ghana, Guinea, Sudano-Sahelain and Uganda. These findings suggested the same amplitude of morphological variation between Central Africa, East and West accessions (Gwali et al., 2012; Sanou et al., 2006; Nyarko et al., 2012). Variation of fruit morphological characters has been reported for the tropical species such as *Balanites aegyptiaca* and *Tamarindus indica* (Soloviev et al., 2004). These variations can be explained by natural and/or human selection, gene flow mediated from genetic drift (Irwin, 2000; Tremblay et al., 2010; Darwin, 1869; Vaughan et al., 2007; Abasse et al., 2011). In addition, rainfall regimes and soil characteristics might be involved in the morphological variations as it was reported in West African provenances (Sanou et al., 2006).

Statistical analysis

Statistical analysis using morphological characters showed high variability of *V. paradoxa* subsp. *paradoxa* growing in the region of Mandoul located in the South of Chad. Individually, these morphological characters were allowed classifying the samples in different morphotypes. Similar results are reported by several authors (Lovett and Haq, 2000a; Nafan et al., 2007). In this study, significant correlations between lamina length and petiole length or between fruit and nut characteristics were observed and it is in agreement with results obtained in provenances from Mali, Côte d'Ivoire and Ghana (Sanou et al*.,* 2006; Lovett and Haq, 2000a; Nafan et al., 2007). Therefore, four main characters as fruit length, fruit width, nut length and nut width were useful to discriminate morphotypes. This assertion confirms the work of Chevalier (1943) who used morphological characters (leave and fruit) to identify eight varieties (*cuneata*, *ferruginea*, *floccosa*, *Mangifolia*, *nilotica*, *parvifolia*, *poissonie*t*serotina*) within *V. paradoxa* subsp. *paradoxa.*

Genetic relationship between shea trees

HCA showed that the use of a single morphological character was not efficient to differentiate the accessions but combining leaf, fruit and nut parameters allowed a good resolution. In this study, each site showed four groups as the dendrogram including all the sites did. These findings were not congruent with the folk classification which identified 6 varieties in the same sites as that of the present study (Mbaiguinam et al., 2007). This incongruence might result from allogamous nature of shea tree which induces phenotypic variation. Phenotypic variation can be influenced by environmental factors or result from genetic variation (Tremblay et al., 2010). Therefore, it is difficult to identify shea tree based on morphological characters alone. The grouping of A11/A30 both from Matekaga and A98 (Matekaga)/A185 (Kol) for example suggested a hybridization by insects pollination or diverse forms of gene flow within or between sites. Hybrids can be problematic for butter quality production because previous studies showed that the morphotypes growing in this area do not produce the same amount of chemical compound (Mbaiguinam et al., 2007). On the other hand, hybridization can be beneficial because high genetic variation induces variability in the population.

Conclusion

Using morphological characters, our study pointed out a high variation of *V. paradoxa* subsp. *paradoxa* populations within and between sites in the region of Mandoul in Southern Chad. A high resolution of the variation was obtained when several morphological characters were combined but a lack of congruence with the folk classification was noticed. The present study can be extended to others Chadian regions were the shea trees are endemic for comparing the local knowledge and for better identification of the morphotypes growing in Chad. Molecular approach can also be used to test if the morphological variation resulted from the DNA polymorphism.

ACKNOWLEDGEMENTS

We would like to thank the University of N'Djaména in Chad for the financial support and the Coopérative des Femmes du Mandoul pour la promotion du Karité (COFEMAK) agents for their help in collecting materials in the different sites. Finally, we would like to thank the anonymous reviewers for their constructive and valuable comments.

REFERENCES

Abasse T, Weber J, Katkore B, Boureima M, Larwanou M, Kalinganire A (2011). Morphological variation in *Balanites aegyptiaca* fruits and seeds within and among parkland agroforests in eastern Niger. Agrofor. Syst. 81(1):57-66.

Abbiw DK (1990). Useful plants of Ghana: West African uses of wild and cultivated plants. Intermediate Technology Publications, London.

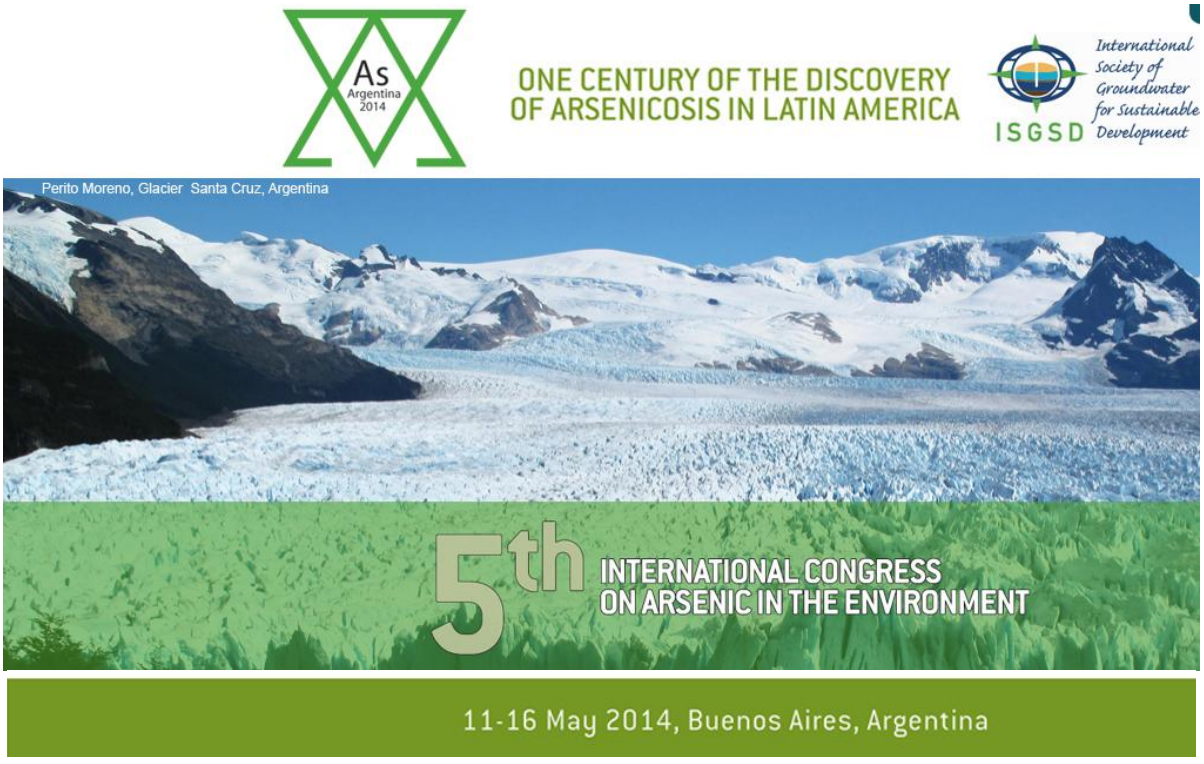
Allal F, Vaillant A, Sanou H, Kelly B, Bouvet JM (2008). Isolation and

characterization of new microsatellite markers in shea tree (*Vitellariaparadoxa* C. F. Gaertn). Mol. Ecol.Resour. 8:822-824.
Byakagaba P, Eilu G, Okullo JBL, Tumwebaze SB, Mwavu EN (2011). Population structure and regeneration status of *Vitellaria paradoxa* (C.F.Gaertn.) under different land management regimes in Uganda. Agric. J. 6 (1):14-22.
Chevalier A (1943). Le karité ou arbre à beurre. Essai monographique. Rev. Int. Bot. Appl. Agric. Trop. 23:100-120.
Chevalier A (1948). Nouvelles recherches sur l'arbre à beurre du Soudan, *Butyrospermum parkii*. Rev. Int. Bot. Appl. Agric. Trop. 28:241-256.
Cidell JL, Alberts HC (2006). Constructing quality: the multinational histories of chocolate. Geoforum 37(6):999-1007.
Darwin C (1869). On the origin of species by means of natural selection: or, the preservation of favoured races in the struggle for life, 5th edn. John Murray, London.
Ferris RSB, Collinson C, Wanda K, Jagwe J, Wright P (2004). Evaluating the marketing opportunities for Shea nut and Shea nut processed products in Uganda. ASARECA/IITA Monograph 5, Ibadan.
Fontaine C, Lovett PN, Sanou H, Maley J, Bouvet JM (2004). Genetic diversity of the shea tree (*Vitellaria paradoxa* C.F. Gaertn.), detected by RAPD and chloroplast microsatellite markers. Heredity 93:639-648.
Gwali S, Okullo JBL, Eilu G, Nakabonge G, Nyeko P, Vuzi P (2011). Folk classification of Shea butter tree (*Vitellariaparadoxa subsp. nilotica*) ethno-varieties in Uganda.Ethnobot. Res. Appl. 9:243-256.
Gwali S, Okullo JBL, Eilu G, Nakabonge G, Nyeko P, Vuzi P(2011). Folk classification of Shea butter tree (*Vitellaria paradoxa* subsp. *nilotica*) ethno-varieties in Uganda. Ethnobot. Res. Appl. 9:243-256.
Hall JB, Aebischer DP,Tomlison HF, Osei-Amaning E, Hindle JR (1996). *Vitellaria paradoxa*: a monograph. School of Agricultural and Forest Sciences, University of Wales, Bangor.
Hemsley JH (1968). Sapotaceae. In: Milne E, Polhill RM (eds) Flora of tropical East Africa. Crown Agents for Overseas Governments and Administrations, London. pp. 47-50.
Irwin RE (2000). Morphological variation and female reproductive success in two sympatric *Trillum* species: evidence for phenotypic selection in *Trillum erectum* and *Trillum grandiflorum* (*Liliaceae*). Am. J. Bot. 87(2):205-214.
Kelly BA, Bouvet JM, Picard N (2004). Size class distribution and spatial pattern of *Vitellaria paradoxa* in relation to farmers' practices in Mali. Agrofor. Syst. 60:3-11.
Lamien N, Tigabu M, Guinko S, Oden PC (2007). Variations in dendrometric and fruiting characters of *Vitellaria paradoxa* populations and multivariate models for estimation of fruit yield. Agrofor. Syst. 69: 1-11. doi:10.1007/s10457-006-9013-x
Lovett PN, Haq N (2000a). Diversity of the Sheanut tree (*Vitellaria paradoxa* C.F. Gaertn.) in Ghana. Genet. Resour. Crop. Evol. 47(3):293-304.
Lovett PN, Haq N (2000b). Evidence for anthropic selection of the sheanut tree (*Vitellariaparadoxa*). Agroforest. Syst. 48:273-288.
Mbaiguinam M, Mbayhoudel K, Djekota C (2007). Physical and Chemical Characteristics of Fruits, Pulps, Kernels and Butter of Shea *Butyrospermum parkii* (Sapotaceae) from Mandoul, Southern Chad. Asian J. Biochem. 2:101-110.
Moore S (2008).The role of *Vitellariaparadoxa* in poverty reduction and food security in the Upper East region of Ghana. Earth Environ. 3:209-245.
NafanD, Bup ND, Kapseu C, Kouame C, Sangare A (2007). Phenotypic Diversity of Shea (*VitellariaParadoxa*C.F. Gaertn.)Populations across Four Agro-EcologicalZones of Cameroon.J. Crop Sci. Biotech. 10 (4):211-218.
Nyarko G, Mahunu GK, Chimsah FA, Yidana JA, Abubakari AH, Abagale FK, Quainoo A, Poudyal M (2012). Leaf and fruit characteristics of Shea (*Vitellaria paradoxa*) in Northern Ghana. Res. Plant Biol. 2(3):38-45.
Okiror P, Agea JG, Okia CA, Okullo JBL (2012). On-Farm Management of *Vitellaria paradoxa* C. F. Gaertn. In Amuria District, Eastern Uganda. Int. J. For. Res. doi:10.1155/2012/768946.
Okullo JBL, Hall JB, Obua J (2004). Leafing, flowering and fruiting of *Vitellaria paradoxa* subsp. *nilotica* in savanna parklands in Uganda. Agroforest. Syst. 60(1):77-91.
R Development Core Team (2011). A Language and Environment for Statistical Computing.R Foundation for Statistical Computing, Vienna.Available at [http://www.R-project.org].Accessed December 22.
Rao KPC, Verchot LV, Laarman J (2007). Adaptation toclimate change through sustainable management and development of agroforestry systems.SAT e Journ. 4(1):1-30.
Ruyssen B (1957). Le karité au Soudan. Agron. Trop. 1:143-178.
Salle G, Boussim J, Raynal-Roques A, Brunck F (1991). Potential wealth of the Shea nut tree.Research perspectives for improving yield. Bois-et-Forets-des-Tropiques 228:11-23.
Sanou H, Lovett PN, Bouvet JM (2005). Comparison of quantitative and molecular variation in agroforestry populations of the shea tree (*Vitellaria paradoxa* C.F. Gaertn.) in Mali. Mol. Ecol. 14(8):2601-2610.
Sanou H, Picard N, Lovett PN, Dembélé M, Korbo A, Diarisso D, Bouvet JM (2006). Phenotypic variation of agromorphological traits of the shea tree, *Vitellaria paradoxa* C.F.Gaertn., in Mali. Genet. Resour. Crop. Evol. 53(1):145-161.
Soloviev P, Daouda Niang T, Gaye A, Totte A (2004). Variabilité des caractères physico-chimiques des fruits de trois espèces ligneuses de cueillette récoltés au Sénégal: *Adansonia digitata*, *Balanites aegyptiaca* et *Tamarindus indica*. Fruits 59(2):109-119.
Tremblay RL, Ackerman JD, Pérez ME (2010). Riding across the selection landscape: fitness consequences of annual variation in reproductive characteristics. Philos. Trans. R. Soc. B. Biol. Sci. 365(1539):491-498.
Ugese FD, Baiyeri PK, Mbah BN (2010). Agroecological variation in the fruits and nuts of shea butter tree (*Vitellaria paradoxa* C. F. Gaertn.) in Nigeria. Agrofor. Syst. 79(2):201-211.
Vaughan DA, Balázs E, Heslop-Harrison JS (2007). From crop domestication to super-domestication. Ann. Bot. 100(5): 893-901.

UPCOMING CONFERENCES

International Conference on Natural Science and Environment (ICNSE 2014), Dubai, UAE, 4 Apr 2014

5th International Congress on Arsenic in the Environment, Buenos Aires, Argentina, 11 May 2014



Conferences and Advert

February 2014
International Conference on Climate Change, Ecology, and Conservation (ICCCEC 2014), Macau, China, 13 Feb 2014

4th International Conference on Ecotoxicology and Environmental Sciences (ICEES-2014), New Delhi, India, 17 Feb 2014

2014 Upwind Downwind Conference: Built Environment - Foundation for Cleaner Air, Hamilton, Canada, 23 Feb 2014

March 2014
5th Conference and Exhibition on Waste Management, Recycling, Environment for South-East Europe, Sofia, Bulgaria, Mar 5 2014

International Forum on Ecology of the Big City, St Petersburg, Russia, Mar 19 2014

2nd International Conference of Plant Biodiversity, Marrakech, Morocco, Mar 27 2014

April 2014
International Conference on Natural Science and Environment (ICNSE 2014), Dubai, UAE, 4 Apr 2014

The NatureServe Conversation Conference on Biodiversity Without Boundaries, New Orleans, USA, 6 Apr 2014

May 2014
10th Ecology and Behaviour Meeting, Montpellier, France

46th International Liege Colloquium on Ocean Dynamics: Low Oxygen Environments in Marine, Estuarine and Fresh Waters, Leige, Belgium, 5 May 2014

5th International Congress on Arsenic in the Environment, Buenos Aires, Argentina, 11 May 2014

3rd International Conference on Water Resources and Environmental Management (ICWRE-2014), Antalya, Turkey, 13 May 2014

June 2014
Ecology and Safety 2014, 23rd International Conference, Burgas, Bulgaria, 8 Jun 2014

International Journal of Biodiversity and Conservation

Related Journals Published by Academic Journals

- *Journal of Ecology and the Natural Environment*
- *African Journal of Environmental Science and Technology*
- *African Journal of Biology and Environment*
- *Journal of Environmental Microbiology and Microbial Ecology*
- *International Journal of Marine Biology and Ecology*

academicJournals